Key Enabling Technologies (KETs) in between smart specialization and (un)related diversification: an empirical analysis of Italian regions.

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Abstract

This paper investigates the determinants of the different patterns of regional diversification that emerge when the place dependence of the development of local capabilities is crossed with the path dependence of technological change. By adopting a recombinant approach to regional diversification and focusing on the complementarity nature of relatedness, we argue that the regional endowment of Key-Enabling-Technologies (KETs) could play an important and possibly differential role in making regions diversify following one rather than another pattern. We also maintain that KETs can be expected to play a role in driving the different trajectories of an 'ideal' escaping transition from a "replicative" kind of diversification, subject to both path and spatial dependence, to a diversification marked by a "saltation" in both respects. Using an original dataset, combining employment and patent data for Italian NUTS3 regions (2004-07 and 2008-10), we estimate a series of ordered probit models, in which the regional propensity to diversify following the identified patterns, depends on the local endowment of KETs knowledge and on a series of regional characteristics. We find that a higher (absolute and relative) endowment of KETs is related to a higher probability of "technology-upon-space" regional diversification between 2004 and 2007, whereas we do not find any effect of KETs on a "space-upon-technology" diversification. This relationship specifically holds for advanced materials and biotechnology, and is robust to endogeneity. During the economic recession, instead, the role of KETS vanishes.

Key-words: related diversification; unrelated diversification, key enabling technology, ordered probit

JEL-Codes: R11, R58, O31, O33

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1. Introduction

The analysis of regional economic diversification is nowadays of upmost importance in both the academic and the policy debate. Research has shown that through 'suitable' patterns of diversification into both new industries and technologies regions can spur growth in terms of employment and (labor and total factor) productivity (Frenken et al., 2007; Boschma and Iammarino, 2009; Boschma et al., 2011; Hartog et al., 2012). These results, along with those on the different regional abilities of taking stock of diversification (Boschma and Capone, 2015; Petralia et al., 2016), have made of it a crucial policy issue too. In the European context, for example, regional policies currently support local innovation contingently on 'smart specialization strategies', which regions are expected to adopt through adequate diversification processes (Boschma and Giannelle, 2014).

In both academic and policy terms, the kind of diversification that appears most beneficial is that inspired by 'relatedness'. On the positive side, regions have been found to frequently diversify in new activities related to preexisting ones in terms of local capabilities of heterogeneous nature (Neffke et al., 2011; Rigby, 2015). Conversely, unrelated diversification appears the empirical exception to the rule of related diversification (Boschma, 2016; Boschma et al., 2017). On the normative side, related diversification has been depicted as a trajectory with lower costs of search for new activities than unrelated one, and thus a lower-risk strategy of mastering their economic control (Balland et al., 2018). Conversely, regional policies that try to develop new unrelated activities from scratch have been stigmatized as 'dead-end' or 'casino' policies (ibid., pag. 9), depending on their targeting activities (technologies) whose complexity (low or high) is likely to provide regions with large and reduced economic returns, respectively.

While relatedness has become the real "driver of regional diversification" (Boschma, 2016), unrelated diversification should not be automatically dismissed, still for positive and normative reasons. On the former side, albeit less frequent, evidence exists about cases of regions whose industrial evolution has occurred through unrelated 'jumps' of industry-path creation (e.g. Isaksen, 2015; Isaksen and Trippl, 2014). On a more systematic basis, evidence is also emerging about conditions that, a different level, make the resort to (un)related diversification (more) less frequent (e.g. Boschma and Capone, 2015; Zhu et al., 2015). From a normative point of view, the (de)merits of un(related) diversification should be balanced against its higher (lower) risks and costs. The local capabilities of the region and its extant knowledge-base are actually a double-edged sword, which not only provides it with opportunities of related growth, but do also pose it a limit to their choice. Indeed, related diversification represents a case of 'place dependence' in the development of new activities that contrasts the acquisition of those, which unrelated diversification would otherwise disclose (Boschma, 2016). Like in the development of new technologies, on which we will return later, this could become problematic when related diversification locks the region in the domain of its extant activities and prevents it to gain longer term development by opening up place-independent market opportunities (Saviotti and Frenken, 2008).

On the basis of the previous considerations, it has been recently claimed that "the issue of related versus unrelated diversification needs to be taken up in future research" (Boschma, 2016, p. 6). In particular, more analysis than the extant one is required about "the conditioning factors that facilitate more related or more unrelated diversification in regions" (ibid). The present paper positions along this prospected research agenda and investigates the determinants of related vs. unrelated regional diversification by trying to fill two gaps in their analysis. The first gap concerns the 'simplified' treatment that regional diversification has received in evolutionary economic geography so far, because of neglecting the socio-technical development of the sectors in which regions specialize and diversify (Boschma, 2016, p. 9). In brief, the analysis of the way in which regions acquire new activities - either new (unrelated) or not (related) with respect to their socio-spatial context - has not retained that such activities could be either new or not to 'the world', being subject to the development of new 'niches' rather than to the consolidation of existing 'socio-technical regimes', respectively. As recently suggested by Boschma et al. (2017), we retain that the radicalness/incrementality of socio-technical development at the sector level can modulate the patterns through which related and unrelated diversification occur and enrich the analysis of the determinants of regional diversification accordingly.

The second gap we address concerns the 'similarity bias' that has characterized the analysis of relatedness in regional diversification so far (Boschma, 2016, p. 10). In accounting for the occurrence of related vs. unrelated diversification, the focus has been mainly placed on the local factors – capabilities, skills, institutions and the like – that make pre-existing activities similar to new ones. Conversely, little attention has been paid to relatedness in terms of 'complementarity' among the local activities through whose combination and recombination new techno-economic ones can be developed. As Castaldi et al. (2015) have recently argued, the 'recombinant approach' to innovation development suggests that the relationships among the extant activities of the region, along with the local socio-technical factors that such relationships can favor, are a crucial conditioning factor of the occurrence of unrelated vs. related diversification. This gap also requires to enrich the analysis of the determinants of regional diversification. In particular, it makes pivotal to investigate the role of the local technologies that could 'enable' the occurrence of unrelated diversification by favoring the development of complementarity among activities that would otherwise be cognitively distant and hard to recombine. We retain this aspect by encapsulating among the determinants of related vs. unrelated diversification the regional endowment of Key Enabling Technologies (KETS). More precisely, we refer to the six KETs recently identified by the EC — industrial biotechnology, nanotechnology, micro- and nanoelectronics, photonics, advanced materials, and advanced manufacturing technologies — as building blocks for a wide array of products and industrial processes, which are deemed crucial for a knowledge-based and sustainable diversification of national and regional economies (EC, 2012a, 2012b).

Following Montresor and Quatraro (2017), we argue and expect that the distinguishing 'enabling' features of these technologies can make of KETs a relevant determinant of regional diversification. In particular, we aim at pursuing two objectives in their analysis. First of all, we investigate whether regional KETs have a differential role in driving related vs unrelated diversification and, eventually, of which kind of it by retaining the radicalness of the sector technologies. In other words, we investigate whether KETs are a general rather than a 'particular' (i.e. unrelated-biased) driver of regional diversification. Second, we investigate the role of KETs in accounting for the regional capacity of escaping the eventual risk of lock-iness by moving from related to unrelated diversification. In particular, by drawing on Boschma et al. (2017), we look at the differential role of KETs in driving two possible trajectories of an 'ideal' escaping transition from a "replicative" kind of diversification, subject to both path and spatial dependence, to a diversification marked by a "saltation" in both respects. A first trajectory is represented by a "technology-upon-space" kind of diversification, in which regions pass through the "transplantation" of an existing regime in developing related activities. The second one is a "space-upon-technology" diversification, in which regions pass through an "exaptation" of a new niche by drawing on related capabilities.

We look at this twofold role of KETS in an empirical application to Italian regions (2004-2007 and 2008-2010) based on secondary patent and employment data. We estimate a series of two ordered probit models, where the probability for a region to enter into progressively more diversified industries from the benchmark case of no-diversification, either by adding technological (new niches) or spatial (unrelatedness) newness to replication, is regressed against its absolute and relative KETS endowment, and on a series of additional regional characteristics. We find that a higher (absolute and relative) endowment of KETs is related to a higher probability of "technology-upon-space" regional diversification between 2004 and 2007, whereas we do not find any effect of KETs on a "space-upon-technology" diversification. This relationship specifically holds for advanced materials and biotechnology, and is robust to endogeneity. During the economic recession, instead, the role of KETS vanishes.

The rest of the paper is structured as follows. Section 2 illustrates the theoretical background of the paper. Section 3 presents the empirical application and Section 4 discusses its results. Section 5 concludes by presenting the research and policy implications of these results.

2. Theoretical background

In evolutionary economic geography, unrelated regional diversification is usually defined as the simple 'complement' to related diversification, in turn generally interpreted in terms of similar capabilities. By differently declining a comprehensive notion of local capabilities (Maskell and Malmberg, 1999), regions (or countries) have been claimed to diversify in a related manner when finding their new activities (industries or technologies) frequently co-occurring with pre-existing ones in their export portfolios (Hidalgo et al., 2007), in that of their technologies (Rigby, 2015) and inter-industry relationships (Neffke et al., 2016; Essleztbichler, 2015; Neffke and Henning, 2013), if not even in the product portfolio of their plants (Neffke et al., 2011). This manifold co-occurrence has actually been taken to reveal, indirectly, the similarity (relatedness) of new to pre-existing activities in terms of labor and capital inputs, workers' skill requirements, user-supplier relationships, and more generic capabilities (Boschma, 2016).

In a complement way, unrelated diversification has been accounted with the absent or negligible similarity between pre-existing capabilities and those required by the development of new industrial paths (e.g. Isaksen, 2015; Isaksen and Trippl, 2014). Still using an indirect approach, evidence of unrelated diversification has been collected by looking for the factors that could attenuate the impact of relatedness (in its different dimensions) on the regional capacity to diversify (Boschma, 2016). In this manner, the relative importance of unrelated diversification has been connected to a variety of conditions at different levels of analysis, such as: at the macro-level, the socio-political conditions of the hosting countries of regional diversification (e.g. West vs. East European countries) (Boschma and Capone, 2016), their level of economic development (Petralia et al., 2016), and the kind of their governance set-up (e.g. liberal vs. coordinated market economies) (Boschma and Capone, 2015); at the meso-level, the core vs. periphery status of the diversifying regions (e.g. in terms of dependence on migration and imports) (Isaksen, 2015), the configuration of their innovation systems (Isaksen and Trippl, 2014), their endowment of social capital (e.g. bridging vs. bonding) (Cortinovis et al., 2016; Antonietti and Boschma, 2018), and of specific kinds of technological knowledge (Montresor and Quatraro, 2017); at the micro-level, the nature (e.g. start-ups vs. subsidiaries of incumbents) of the diversifying plants and the location (e.g. regional vs. extra-regional) of their control (Neffke et al., 2016); the inflow of multinational corporations with specific entry strategies (Cantwell and Iammarino, 2003) and of specific kinds of migrants (e.g. return) (Saxenian, 2006); the presence of universities (Gilbert & Campbell, 2015; Lester, 2007; Tanner, 2016), of 'smart-thinking' government structures (Foray, 2014), and of collective actors contributing to the institutional kind of entrepreneurship that unrelated diversification requires (Marquis and Raynard, 2015; Sotarauta and Pulkkinen, 2011; Strambach, 2010).

While it has led to identify an already rich set of factors, the analytical framework based on the similarity/dissimilarity of local capabilities described above is far from capturing the full complexity of regional diversification. As Boschma (2016) has pointed out in a recent critical review, some additional aspects need to be considered to enrich the analysis of related vs. unrelated diversification, among which in this paper we focus on two.

2.1. Regional diversification in-between place and path dependence.

The first aspect to consider is that the place dependence to which the standard analysis of relatedness refers – new regional activities depend on previous ones available in loco – does not exhaust the complexity of regional diversification. As Boschma et al. (2017) have recently argued, regional diversification actually embraces (at least) an additional dimension than the socio-spatial (similar local capabilities), on which evolutionary economic geography has focused so far. This second dimension rather relates to the evolution of the 'socio-technical regimes' that characterize the sectors in which regions operate and diversify, and on which the transition literature has instead focused (Geels, 2002; Kemp et al., 1998; Markard et al., 2012; Rip and Kemp, 1998).

At a certain moment in time, each sector actually reveals a coherent alignment of socio-technical elements like "… scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures" (Rip and Kemp, 1998, p. 338). Such an alignment typically makes the sector resist radical innovations of disruptive nature, which threaten the coherence of the regime. Conversely, socio-technical regimes favor path dependence in the development of technologies and rather stimulate incremental innovations and gradual change. Still, following the same view, radical novelty is not excluded and could occur in the sector, typically with the experimental creation and eventual upscale of 'niches'. These are socio-technical environments, which enable the incubation of new radical technologies by playing two functions: i) protecting the nascent technology from the consolidating pressure of the regime; ii) allowing the relevant actors to experiment and familiarize with its novelties (Coenen et al., 2010; Geels, 2002).

While connected to the technological system that underpins a sector, both regimes and niches have a fundamental social nature. On the one hand, regimes emerge through the institutionalization of rules and practices that concern the development, exploitation and diffusion of the extant technology, which require the active involvement of communities of practitioners. On the other hand, niches need to be actively created by actor groups that mobilize resources on a new industry (Simmie, 2012; Dewald and Truffer, 2012). What is more, they require an institutional work of entrepreneurship to get upscaled and reach the momentum for their successful development into a new regime (see Smith and Raven, 2012). Because of their social nature, both regimes and niches do have a place nature too, which the transition literature is hesitating to recognize (Truffer and Coenen, 2012). On the one hand, while they typically emerge and diffuse through pervasive international networks and thus constitute global structures (Fuenfschilling and Binz, 2016), socio-technical regimes do show local heterogeneity, as they are not uniformly spread and cogent in all regions (Späth and Rohracher, 2012). On the other hand, while they might themselves get connected through international networking (Sengers and Raven, 2015), niche formation and development are typically a regional process, which is contingent on a variety of place-specific factors (Boschma, 2016).

Given its spatial connotation, the transition of socio-technical regimes poses regions in front of a ‘path dependence’, which interacts with the ‘place dependence’ of the development of local capabilities. Their combination yields different patterns of regional diversification, depending on the extent to which the relative dependence gets contrasted in the search of radicalness. This is the rationale of the taxonomy of regional diversification patterns that Boschma et al. (2017) put forward by crossing its radicalness along the regional dimension (related versus unrelated) with that along the sectoral dimension (regime versus niche) (Table 1). In so doing, regional diversification can take on four possible configurations, which the authors call: i) “replication”, in which regions diversify in a related way by sticking to an established socio-technical regime; ii) “transplantation”, in which regions develop industries unrelated to the local domain, but by still sticking to the dominant socio-technical regime; iii) “exaptation”, in which the existing knowledge-base of the regions is diversified in a related manner, but by developing the niche for a new sector; iv) “saltation”, in which activities are developed that are new both to the region and to the world in technological terms.

Insert Table 1 about here

As Boschma et al. (2017) illustrate, the four configurations can be argued to differ in terms of the risk they entail, the institutional work they require, the key-actors of their undertaking, and their local vs. global spatial-logic. Arguably, albeit this is only implicitly retained in their paper, the four diversification strategies also differ in their conditioning factors, which make regions differently prone to embrace one rather than another of them. Among these factors, one that deserves special attention, and on which we focus in this paper, is the regional capacity to exploit relatedness along a complementarity, rather than a similarity dimension. To this aspect we turn in the following section.

2.2. Relatedness in-between similarity and complementarity

As we said, the analysis of regional diversification has so far considered relatedness as synonymous of ‘similarity’ in local capabilities as well as in related local dimensions, focusing on the potential spillovers between activities that share common knowledge, skills, resources, user-producer interactions and the like. As Boschma (2016) recognizes, this is different from the less diffused consideration of relatedness in terms of ‘complementarity’ between the products or technologies through whose combination and recombination regional diversification can be claimed to occur (Broekel and Brachert, 2015), following a regional declination of the Schumpeterian theory of ‘recombinatory innovations’ (Castaldi et al., 2015; Fleming, 2001; Weitzman, 1998). On this basis, it can be claimed that regions diversify in a related manner when they develop new activities by differently recombining local capabilities, which had already been combined somehow in the past. Conversely, unrelated diversification would emerge when to be combined are either non-local capabilities, for whose combination regions rely on boundary-spanners (like MNE and/or migrants), or local capabilities that had never been combined before, yielding a true case of Schumpeterian ‘Neue Kombinationen’. The rationale of the distinction is straightforward and similar to the one that applies to organizational learning in management studies (Arts and Veugelers, 2015; March, 1991): (re)combining knowledge along an already established path would lead regions to ‘exploit’ local capabilities in order to master incrementally new activities; following new paths of (re)combination, instead, enable regions to ‘explore’ the acquisition of radically new activities.

As it appears evident, the recombinatory approach requires us to focus on the complementarity relationships between local capabilities and activities as a possible determinant of related (high complementarity) vs. unrelated (low complementarity) diversification, as well as on those factors that such a complementarity can eventually reinforce.

A similar complementarity focus is also required in searching for the determinants of regional diversification when, referring to Boschma et al.’s (2017) taxonomy, the transition towards new socio-technical regimes is considered in its unfolding. The relevant approach here is that based on the “bricolage” mode of creating new industry-paths, to which the forerunners of the transition literature has pointed (Garud and Karnøe, 2003). Following such a mode, the development of a new industry – or the development of a niche in the transition jargon – would pass through a creative, experimental alignment of diverse and distributed sets of technologies and institutions, through which networks of distributed actors would implement a “mindful deviation” from the dominant configuration – or socio-technical regime, in the transitionist language. Conversely, the continuation of an existing industry – that is, the endurance of its underlying socio-technical regime – would be based on the exploitation of the coherence previously enriched by incumbent actors among technologies and institutions that have become established and vested, respectively.

Although with a different declination with respect to the radicalness along the regional dimension, also the radicalness of regional diversification along the industry dimension appears thus accountable by the complementarity that marks the development of niches (low complementarity) and the endurance of regimes (high complementarity). In turn, also this aspect makes the analysis of the factors that such a complementarity can affect of extreme relevance in investigating (un)related regional diversification. As we will claim in the following, an important enabler of complementarity is represented by the local endowment of Key-Enabling-Technologies (KETs).

2.3. KETs and regional patterns of diversification

The set of factors that can help in connecting the activities through whose recombination regional diversification unfolds, and can thus increase their relatedness in terms of complementarity, is of course ample. Labor mobility, for example, can be an important means for exchanging skills and knowledge required by plants of different sectors and for identifying new job opportunities at their cross-road (Boschma, 2016). The production structure of the region, in terms of input-output linkages, can also represent a network through which the knowledge of diverse industries gets embodied in the respective products/services and diffuse by increasing their complementarity and opportunities of structural change across them (Essletzbichler, 2015). The regional presence of institutional entrepreneurs and collective actors, like industrial associations or unions, can be another means of knowledge diffusion and creative inter-industry complementarity (Garud et al., 2007).

When we look at the technological knowledge-base of the region, an important complementarity enabler is represented by its endowment of technologies that have a ‘general purpose’ in their application. This could be the case of the standard GPT of the last two centuries – e.g. electricity, electronics, control theory (automation), and the Internet – and, more recently, of the technologies identified (by the EC) as key enablers (KETs) of the transition towards a knowledge-based and sustainable economy – i.e. industrial biotechnology, nanotechnology, micro- and nanoelectronics, photonics, advanced materials, and advanced manufacturing technologies.

The role of KETs in driving regional branching has been recently identified by Montresor and Quatraro (2017). Looking at the patent applications of European regions over the period 1998-201, the authors found that the regional control (specialization) of (in any of the) KETs as a twofold effect: on the one hand, it augments the number of new technologies that the region comes to master and increases the regional capabilities to diversify; on the other hand, it attenuates the role of relatedness in driving the same process, by making regional diversification more unrelated.

According to Montresor and Quatraro (2017), the regional branching effects of KETs are due to their distinguishing enabling properties, which make them relevant also in addressing our research questions. The first characteristic of KETs refers to the co-invention-application pattern of their development (Bresnahan, 2010), in which a KETs inventions typically co-occurs with an innovative use of it in the (regional) context in which it has been introduced (e.g., the application of a newly invented biotechnology to a new maritime resources exploitation). Thanks to this property, the regional activities that are based on the applicative path of an extant technology becomes connectable, not only to the complementary activities of related technologies, but also to the non-complementary ones based on the new inventive path that KETs has created. In other words, by co-creating new regional inventions and applications, KETs development can allow the region to implement recombinations of local activities that the simple branching of the extant application would not have made possible and thus to increase its capacity of unrelated diversification. Referring to Boschma et al.'s (2017) taxonomy and considering the two variants of unrelatedness it comprehends, in the light of their first property KETs could be expected to favor a 'transplantation', if not even a 'saltation' pattern of diversification.

The second distinguishing feature of KETs is their horizontal application pattern, which covers the entire spectrum of activities of a regional economy. Indeed, the feasibility-study through which the six KETs have been identified provides a clear picture of the large number of products and services of which they represent a crucial input (EC, 2012a; 2012b). Because of their general-purpose, the advancement of KETs knowledge has the crucial implication of moving the general technological frontier of the region ahead (Bresnahan, 2010) and, in so doing, attenuating the constraints that the ruling socio-technical regimes pose to a radically new recombination of existing ideas (Olsson and Frey, 2002). In other words, KETs development could provide regions with an extra buffer of knowledge and ideas, which can be combined in such an afresh way to reach an extra-regional kind of novelty and eventually favor the development of new socio-technical niches. In the taxonomy proposed by Boschma et al.'s (2017), retaining the eventual co-presence of relatedness rather than unrelatedness, this second property could make

KETs capable to drive an ‘exaptation’, if not even a ‘saltation’ pattern of diversification.

On the basis of the previous arguments, while it can be confirmed as relevant, the role of KETs in driving regional diversification appears more nuanced than it has been previously established (Montresor and Quatraro, 2017). First of all, KETs can be expected to be more enabling of non-replicative patterns of diversification than replicative ones, which could be even disfavored by the recombinatory tendency of KETs. Second, KETs are possibly more enabling of a transplantation kind of diversification than of an exaptation one, as the latter is conditional on the KETs capacity to generate recombinations whose novelty come to extends over the regional boundaries. For a similar argument, the same conditionality applies to the capacity of KETs to drive a saltation kind of diversification. In synthesis, our first expectation is that KETs are actually a differential driver of regional diversification, possibly capable to explain their heterogeneous geographical distribution.

A second argument that the properties of KETs lead us to formulate concerns a normative, rather than a positive evaluation of their role in driving regional diversification. As we said, while possibly less risky, a replication strategy could lead regional diversification to a double lock-iness, in both path and spatial dependence, which could even lead diversification to a halt (Boschma, 2016). Although more risky, higher opportunities of long term development accrue to the region from a saltation strategy, in which diversification is both unrelated and oriented to the establishment of a new technology. Thinking of the shift from a replication to a saltation diversification as an ‘ideal’ (albeit risky) strategy to escape regional lock-in situations, the recombinatory properties KETs could have in favoring the development of unrelatedness and/or new niches make of them a potential driver of the same transition. In brief, should the two properties of KETs exert their expected effects, we could expect them to be a driver of the replication – saltation transition. On the other hand, it could be more interesting to investigate whether, because of a possibly differential working/weight of the two properties, KETs have a differential role in driving two possible trajectories that, sticking to Boschma et al’s (2017) taxonomy, could lead regions from replication to transition. A first trajectory can be termed “technology-upon-space diversification” and is one in which the diversification transition passes through an intermediate transplantation pattern (Table 2). In brief, regions first exploit an existing (global) regime to diversify their economic activities into unrelated regional domains, and then “stretch” the novelty to the technology level and enter a new niche.

A second trajectory, which is instead intermediated by an exaptation pattern, can be termed “space-upon-technology diversification”. In this case, regions first enter a new technological domain (niche) to diversify “around” their extant economic activities, and then “stretch” the new technology to get into unrelated regional domains too.

Insert Table 2 about here

As it can be seen, both of the trajectories entail a progressively more novel recombination of the extant regional activities, so that KETs could be expected to help in both. Similarly, we do not have theoretical and empirical arguments to expect their eventual impact could be larger for one rather than for the other trajectory. Accordingly, we leave this aspect to be ascertained by the empirical application, to which we turn in the next Section.

3. Empirical application

3.1. Data

Our empirical application relies on two data sources. In order to measure the regional patterns of diversification at stake we use data from the Statistical Archive on Active Firms (*Archivio Statistico Imprese Attive – ASIA*) provided by the Italian Statistical Institute (ISTAT). These data provide information on number of plants and employees, by industry (up to the five-digit level) and region (at NUTS3 level which corresponds to Italian administrative provinces). Our unit of observation is thus the five-digit industry *i* in the NUTS3 region *r.* Although data are available from 2004 to 2010, in 2008 ISTAT followed EUROSTAT instructions and revised the classification system of industries, from ATECO 2002 (i.e. NACE Rev. 1.1) to ATECO 2007 (i.e. NACE Rev 2). Since some sectors changed their industry belonging, for example passing from manufacturing to services and vice versa, the available industry classification in the two periods is not comparable and forces us to split the sample in two. While this impedes us to carry out a dynamic analysis, on the other hand, it enable us to investigate whether the testing of our arguments could differ between 2004-07, as the period before the arrival of the economic crisis, and 2008-10, as the crisis period. In the former period, we count 756 five-digit industries distributed across 103 provinces, for a total amount of 63,449 observations[1]. In the latter, the number of five-digit industries is 805 and observations are 67,485.

The second source of information is OECD-REGPAT database, from which we draw information on the regional endowment of KETs, using the IPC classificatory scheme of the EC feasibility study on KETs (EC, 2012b). Specifically, we consider patent

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[1] Note that industries are not uniformly distributed across NUTS3 regions.

applications to the European Patent Office (EPO) in these IPC classes and we pool them together in order to identify KETs, using the applicant address to assign patents to NUTS3 regions […extend …].

In addition to these main sources of data, we also draw on official regional ISTAT statistics for other info and on data from the Italian Ministry of University and Research for dealing with the endogeneity of KETs data (see below).

3.2 Variables

3.2.1. Dependent variables

We define two ordered variables of the three kinds of diversification patterns described above (see Section 2.1). As our data only allow to observe these patterns for two short periods of time (2004-2007 and 2008-2010), we are unfortunately incapable to investigate the escaping strategies from non-diversification that regions could undertake over time. However, in a cross-sectional setting, we can address the region capacity of creating new industries according to a concomitant set of diversification patterns, which we can assume as progressively more "diversified" at the same point of time. Such a capacity could actually provide insights about the capacity the region could have of actually moving from one to another pattern of diversification, should data permit to observe it over time.

The first dependent variable, $Tech\text{-}Space\text{-}Diver_{r,T}$, proxies region *r'*s capacity of getting at time *T* progressively more "diversified" industries with respect to those at *T-t*, consistently with what we called "technology-upon-space diversification" (see Section 2.3). Such a variable orders the three possible kinds of diversification we are considering with respect to the benchmark case of no-diversification (value 0) as follows: replication (value 1), transplantation (value 2), and saltation (value 3). The second dependent variable, $Space\text{-}Tech\text{-}Diver_{r,T}$, accounts for the same capacity consistently with a "space-upon-technology diversification", and is still an ordered one with the following specifications: no-diversification (value 0), replication (value 1), exaptation (value 2), and saltation (value 3).

We operationalize the taxonomy of diversification strategies proposed by Boschma et al. (2017) in Table 2, by looking at the entry of regions into new economic activities through job creation: that is, by looking at the appearance of employment in five-digit industries from time *t-m* to time *t* (Neffke et al., 2016). Specifically, we consider as an *entry* a new five-digit industry (with at least one employee[2]) that appears in 2007 (2010) with respect to 2004 (2008). To see whether these new entries are related or not to existing regional capabilities, we adopt the following

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[2] We also fixed a threshold to five employees, but, in doing so, we halve the amount of entry events and we are not able to observe any clear diversification in Italian regions.

approach. We consider as *related* a new five-digit industry (in 2007) that belongs to an incumbent three-digit industry (in 2004) in the region, that is, a three-digit industry with a non-zero level of employment in 2004. Conversely, we consider as *unrelated* a new five-digit industry (in 2007) that belongs to a new three-digit industry (with respect to 2004) in the region, that is, a three-digit industry that did not exist in 2004[3].

As for the technological novelty of the diversification, we instead look at employment creation within (*regime*) and outside (*niche*) "the world" in which technologies are developed and translated into new economic activities. The extant socio-technical regime is ideally defined on a global scale and new to the region industries should be related to technologies/industries that are new or not to such a global world. On the other hand, because of data constraints, we are unfortunately forced to refer to the (much) smaller word represented by the country in which the regions are located, that is, Italy. In other words, we retain as '*new to the world' niches* at time *t* those five-digit industries that did not exist in the country (i.e. with zero employment) in *t-k*. Similarly, we consider as '*new to the region niches'* those five-digit industries at time *T*, which are already existing in the country at *T-t*, as expression of the extant socio-technical regime, but not into the region under observation. This is a substantial simplification of the degree of technological novelty that regions can experience in their diversification strategy. Still, being a forerunner in a new industry within the country can be assumed to expose the region to at least some of those processes of experimentation and radical innovation that a new "real" niche would entail.

Combining the previous two arguments, we define the constitutive items of our dependent variables (*Tech-Space-Diver* and *Space-Tech-Diver*) as follows. We define:

- *replication* as a new 5-digit industry at *T*, whose 3-digit industry already existed at *T-t*, both in the region and in Italy (neither new to the region, nor to the world);
- *transplantation* as a new 5-digit industry at *T*, whose 3-digit industry did not exist in the region, but already existed in Italy at *T-t* (new to the region, but not to the world);

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[3] As a robustness check, we also use the location quotient, at three-digit level, to discriminate between a related and an unrelated entry. In this case, we consider as related, a new five-digit industry that belongs to a three-digit industry of specialization for the region, i.e. a three-digit industry with a location quotient that is higher or equal than 1. An *unrelated entry* is, instead, a new five-digit industry that belongs to a three-digit industry of de-specialization for the region, i.e. a three-digit industry with a location quotient that is lower than 1. The results of the estimates do not change, but, adopting this approach, we observe more cases of transplantation than replication, which seems to contradict the stylized fact according to which regions are more likely to diversify in related rather than in unrelated activities.

- *exaptation* as a new 5-digit industry at *T*, whose 3-digit industry already existed in the region, but did not in Italy at *T-t* (new to the world, but not to the region);
- *saltation* as a new 5-digit industry at *T*, whose 3-digit industry did not exist in *T-t*, neither in the region nor in Italy (new to the region and new to the world).

Table 3 shows the distribution of all these variables in the sample, and across the two periods. Before the arrival of the economic recession, i.e. in 2004-07, we observe all the four cases of regional diversification. In particular, we note that replication is the most frequent option (explaining three quarters of entries), whereas, as expected, saltation represents the rarest, with only 16 cases (0.6% of entries). Looking at the industry distribution of *saltation*, we also note that it is concentrated in one single three-digit industry, i.e. ATECO code 652 "other financial intermediation". For this reason, we chose not to include it in the regression analysis, and build our ordinal dependent variables using the other three diversification modes. During the economic crisis, i.e. in 2008-10, we observe a smaller number of entries with respect to 2004-07 and we do not register any case of exaptation and saltation. Therefore, we cannot identify the corresponding *Space-Tech-Diver* variable, but we use only *Tech-Space-Diver*.

Insert Table 3 about here

3.2.2. Focal regressor

Our focal explanatory variable is the local endowment of KETs. To avoid simultaneity with our regional diversification variables, we measure it in the three years before our dependent variables, i.e. 2002-04 and 2006-08 respectively. Following innovation studies, we consider patent applications as a proxy (although not free from limitations) of the knowledge stock of the region, accumulated through the inventive activities located in there. Accordingly, we first define $KETs\text{-}Pat_{r,T\text{-}t}$ for the two periods as the number of patent applications by residents in region *i* between 2002 and 2004 (2006 and 2008), which include KETs-related IPC-codes (according to the EC taxonomy of their identification (see EC, 2012)).

As we argued in Section 2.3, KETs work by recombining the different domains of knowledge on which the region draws in carrying out its economic activities. Accordingly, we proxy this basket of re-combinable knowledge by counting all of the patent applications of region *i* in the period 2002-2004 (2006-2008), showing other than KETs-related IPC-codes, $Non\text{-}KETs\text{-}Pat_{r,T\text{-}t}$.

We argue that the "size" of this last set of knowledge matters in two respects. On the one hand, the regional capacity of entering into progressively more diversified industries, either through a *Tech-Space-Diver* or through a *Space-Tech-Diver* logic, can be affected by the already available non-KETs knowledge domains. This knowledge stock can either increase or decrease the potential for regional diversification. Indeed, an increase in its size could enlarge the scope for possible re-combinations driving diversification. However, if already ample, the available knowledge set could make the scope for further re-combinations saturated and even decrease the regional capacity of diversifying in progressively more diversified manners. On the other hand, $Non\text{-}KETs\text{-}Pat_{r.T\text{-}t}$ can be also expected to condition the effectiveness of the complementarity role of KETs (i.e. $KETs\text{-}Pat_{r,T\text{-}t}$). An increase in the knowledge-items to combine and complement could actually make this role more difficult to play and demand an increase in KETs too. In order to account for this last issue, we compute the relative KETs endowment as additional regressor, by relating $KETs\text{-}Pat_{r,T\text{-}t}$ to $Non\text{-}KETs\text{-}Pat_{r,T\text{-}t}$. Then, we use the *KETs/NonKETs* ratio alternatively to an initial specification in which they are separately included[4].

Figures 1 and 2 show the geographical distribution of the total amount of KETs (KETs-Pat) and of each single KET respectively, by period.

Insert Figure 1 about here

Insert Figure 2 about here

Figure 1 shows that KETs endowment is higher in Northern regions, even though we find evidence of a very high stock of KETs in some regions in the Centre and the South[5]. When we look at the spatial distribution of each single KETs in Figure 2, we find that advanced manufacturing technologies and advanced materials are the most diffused, whereas nano-technologies are concentrated in few regions in Italy. In addition, this distribution looks stable over time.

3.2.3. Relatedness variables and other regional characteristics

The evolutionary economic geography literature stresses that the capability of a region to further diversify across space and time depends on the initial degree of relatedness among existing activities (Neffke et al., 2011; Boschma et al., 2013; Balland et al., 2017; Boschma 2017; Cortinovis et al. 2017). To capture how relatedly distributed are the existing activities in Italian NUTS3 regions, we thus include a measure of related ($RV_{r,T\text{-}t}$) and unrelated variety ($UV_{r,T\text{-}t}$). Following Frenken et al. (2007), we compute the within and between entropy indices, using five-digit and

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[4] The use of the *KETs-Pat/Non-KETs-Pat* ratio is also due to the high correlation between the two patent stocks.

[5] We also run a Moran-I test of spatial autocorrelation for both the absolute and the relative KETs endowment. In each period, and for each of them, the test never rejects the null hypothesis of absence of spatial autocorrelation.

two-digit industries as reference. Specifically, our industry variety measures are the following:

$$[1]\ RV_r = \sum_{i=1}^{I} P_i H_i\ ,$$

where P_j represents the two-digit employment shares, $P_i = \sum_{k\in S_i} p_k$, *k* is the five-digit industry falling under the two-digit industry S_j (*j*=1…*J*), and p_k represents the five-digit employment shares, and the following positions hold:

$$[2]\ H_i = \sum_{i\in S_i} \frac{p_k}{P_i} log_2 \left(\frac{P_i}{p_k}\right), \text{ and}$$

$$[3]\ UV_r = \sum_{i=1}^{I} P_i log_2 \left(\frac{1}{P_i}\right).$$

We still follow the extant literature and expect that our trajectories of progressively more diversified diversification positively depend on the level of economic complexity of the focal region (Pinheiro et al. 2018). This is in turn connected to the evolution of their level of economic development. At low level of it, regions enter into activities that are of a low complexity, and these activities are the most related. As the level of development increases, so does the degree of product complexity, which increases the potential for unrelated recombinations. In order to measure such a complexity, we use Hidalgo and Hausmann's (2009) methodology with respect to 2004 and 2008 export data for Italian NUTS3 regions and three-digit industries provided by Coeweb, ISTAT. At first, we compute the ubiquity of an industry, as the number of regions that export the products of (three digit) industry *j* with a revealed comparative advantage, M_{rj} (taking value 1 if the region *r* has a comparative advantage in industry *j*, and of 0 otherwise), that is, $k_r = \sum_r M_{rj}$. We then compute the economic complexity (*ECI*) of a region as the average knowledge intensity of all the exporting industries:

$$[4]\ ECI_r = \frac{\sum_j M_{rj} ICI_j}{k_r}$$

where $ICI_r = \frac{\sum_r M_{rj} ECI_r}{k_j}$ is the knowledge intensity of an industry *j*, that is the average knowledge intensity of the regions that export its products. Putting the two equations together, and using the eigenvalues method, we can define the *ECI* as follows:

$$[5]\ ECI_i = \sum_j \frac{M_{ij}}{k_i k_j} \sum_i M_{ij} ECI_i.$$

In brief, the region’s complexity is its specialization in products that are less ubiquitous, but also exported by more diversified (so more complex) regions, where these latter are defined as regions exporting a large number of less ubiquitous products.

A further diversification variable that we consider is the human capital of a region. Being a potential source of innovation in a region, as well as a source of entrepreneurship, we could expect a higher capability to discover new, unrelated, pathways in regions that are more endowed of highly educated individuals. However, a higher amount of human capital can also represent a potential obstacle to regional diversification, to the extent at which discovering radically new activities makes existing knowledge and capabilities rapidly obsolete, thus requiring the existing workforce to be (re-)trained. With the ambiguous expectation, we measure the human capital of the region ($HK_{r,T-t}$) through the share regional resident population holding a university degree, using 2001 ISTAT Census data.

Following Neffke et al. (2018), we also consider the role of external agents as drivers of (unrelated) regional diversification. Specifically, we consider the role of inward greenfield FDI, as incoming projects that are aimed at establishing a new activity in the region implying a long-lasting interest by a foreign investor. We do expect that, the higher the amount of inward FDI, the higher the amount of knowledge accruing from outside the region (and the country), the higher the chances to learn, and combine, external knowledge with incumbent capabilities to generate new, unrelated, activities. In particular, we do expect inward FDI to be related to a higher propensity to diversify through a *Tech-Space-Diver* way. The data to measure the variable at stake come from the FDI Markets database provided by Financial Times Ltd, which shows the NUTS3 destination regions for each FDI project directed to Italy. On this basis, $FDI_{r,T-t}$ counts the number of incoming greenfield FDI at the regional level.

Another factor that the literature has shown to affect the regions’ capacity of unrelating their diversification is their level of social capital. In particular, Cortinovis et al. (2017) and Antonietti and Boschma (2018) have recently found that the effect of social capital depends on its nature. A higher endowment of what is called “bridging social capital” - referring to cooperative connections and inclusion practices that help the interaction of people belonging to different networks/communities - has been found related to a higher capability to diversify into unrelated activities. Conversely, bonding social capital - referring to the role that networks have in bringing together people who already share important sociocultural, exclusive, traits - can potentially work in locking-in regions into existing capabilities and in preventing them from discovering new opportunities. On the basis of these results, we expect that bridging social capital could favor our *Tech-Space-Diver*, as this is a pattern of diversification where the region (re)combines internal capabilities passing through an intermediate transplantation pattern. Differently, we expect that bonding social capital could favour *Space-Tech-Diver*, since this trajectory is based on the capability of regions to first develop a new niche using its own capabilities. In order to test for these hypotheses, we include among the regressors a proxy for each of the two forms of social capital. Bonding social capital, $BOND\_SK_{r,T-t}$, is built up by following Crescenzi et al. (2013) and Antonietti and Boschma (2018) with respect to ISTAT data. Using data from the "Kinship and intergenerational solidarity" survey administered by ISTAT, we consider the following two variables (both referred to 2003): (i) the number of families having lunch at least once per week with relatives and close friends; (ii) the number of young adults who live with their parents. The former is used as a proxy for the frequency of interactions, while the latter should capture the social proximity among individuals. We normalize these variables *x* as follows: (*x-min*)/(*max-min*), so to make *x* range between 0 and 1. Since these variables are recorded only at NUTS2 regional level, we consider a third element that, instead, is made available at the NUTS3 regional level: the number of resident family units in the NUTS3 region, as provided by the 2001 Census of population. We divide this number by the total number of resident family units in the corresponding NUTS2 region so to obtain the share of resident family units for each Italian province. Then we compute the weighted mean of the previous two normalized components, using the share of resident family units as a weight. In this way, our proxy of bonding social capital varies at the NUTS3 regional level and a higher weight is assigned to provinces with a larger share of family units.

Bridging social capital, $BRID\_SK_{r,T-t}$, is instead measured using data about the number of blood donations per 1,000 inhabitants (in 2002) and the number of voluntary associations per km^2 in 2001-02. Information is taken from Cartocci (2007) and available at the NUTS3 level. As before, we normalize each variable and then we compute the mean of the two normalized components.

3.2.4. Control variables

We also add a series of regional characteristics to control for potential omitted variables and unobserved heterogeneity. Among them, we include:

- the level of regional value added per capita (*VAPC*), to proxy for the average level of economic development;
- the 2001-04 (2005-08) growth rate of VAPC (*GROWTH*), to account for the economic dynamism of the region;
- population density (*POPDEN*), as given by resident population per km^2, to capture the amount of urbanization economies and the presence of large urban areas, where innovative activities tend to be located more frequently;

- trade openness (*TRADE*), given by the sum of imports and exports on regional value added.

Finally, we add a series of NUTS2 region dummies and 2-digit industry dummies to account for fixed effects at regional and industry level. Table 4 shows the main summary statistics.

Insert Table 4 about here

3.3. Econometric strategy

We estimate the following model:

[6] $Y_{r,T} = \beta_0 + \beta_1 KETS_{r,T-t} + \boldsymbol{X_{r,T-t}\beta_2} + \varphi_r + \mu_j + \varepsilon_i,$

where $Y_{r,t}$ refers to our ordinal diversification variable (*Tech-Space-Diver* and *Space-Tech-Diver*) for region *r*, *T* is equal to 2007 (2010) and *T* - *t* is equal to 2004 (2008) in the two considered periods, respectively.[6]

As we said, KETs is measured either in absolute or in relative (with respect to non-KETs) terms, and is cumulated backward from 2004 (2008) for three years in the first (second) sample estimates. Vector $\boldsymbol{X_{r,T-t}}$ includes the relatedness and explanatory diversification variables we have identified, as well as the selected controls. φ_r and μ_j represent, respectively, the NUTS2 region and 2-digit industry dummies.

Since *Y* is an ordered variable, we estimate Equation 6 through an ordered probit regression model, and we cluster the standard errors at NUTS3 regional level. In such a setting, a significant and positive (negative) KETs coefficient, β_1, tells us that the regional endowment of KETs increases (decrease) the regional capacity of entering into progressively more diversified industries, according to the selected diversification trajectory taken as dependent variable. The marginal effects extracted from the same ordered probit instead informs us about the role of KETs in driving the regional capacity of diversifying according to one of the constituent diversification patterns of *Tech-Space-Div* and *Space-Tech-Div.*

One issue concerns endogeneity. The relationship between KETS endowment and regional diversification can be affected by unobserved heterogeneity and simultaneity. For instance, it can be that an unobserved, unpredicted, positive or negative shock can affect both variables, by altering the patent intensity of a region and its capability to generate new activities. Alternatively, it can be that local,

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[6] We also estimate Equation 6 adding the saltation mode to the two dependent variables. Results, available on request, do not change.

unobserved characteristics make new and unrelated industries to emerge in regions that are more endowed with KETS, but without these latter can play a clear role. We deal with these issues in three ways. First, we measure KETS endowment before the materialization of new activities in a region, so avoiding any type of observable simultaneity between *Y* and *KETS*. Second, the fact of splitting the sample in two allows us to consider the different relations between *Y* and *KETS* before and during a pervasive negative shock like the 2008 recession. Third, we also adopt an instrumental variable approach, using an extended ordered probit regression model, which accommodates the inclusion of endogenous covariates[7] (Wooldridge, 2014).

As an instrument, we use the regional stock of academics (research assistants, assistant, associate and full professors) belonging to hard sciences, that is to the following scientific areas: mathematics, physics, chemistry, biology, engineering, architecture, hearth science, agriculture and medicine. Data are obtained from the public website of the Italian Ministry of Education and Research (MIUR)[8], and refer to the amount of scholars employed in Italian universities at 31 December 2001. More precisely, the information refers to the actual personnel employed by each University in Italy, which we have assigned to a region according to the location of its legal head office. Since the production of KETS is highly science-based, or technology-push, a higher regional endowment of hard science scholars should be related to a higher KETs endowment. However, the relationship with regional diversification is not clear *a-priori*. It is well known that universities generate new entrepreneurial activities through spin-offs and innovative start-ups, but the fact that these activities are unrelated to the existing knowledge base of the region is still under-investigated. As a partial proof of that, the pairwise correlation between our instrument and the absolute KETS endowment is 0.59 (statistically significant at 1% level), whereas that with *Tech-Space-Diver* and *Space-Tech-Diver* is, respectively, -0.025 and -0.018 (not statistically significant).

4. Results

Tables 5 to 10 show the results of the ordered probit estimates. Table 5 shows the ordered probit estimates for *Tech-Space-Div* (Columns 1 and 2) and *Space-Tech-Div* (Columns 3 and 4) with respect to the first period, 2004-07. In particular, Columns (1) and (3) refer to the specifications in which *KETs-Pat* and *Non-KETs-Pat* are considered separately, while Columns (2) and (4) refer to the specifications with *KETs/Non-KETs*. To start with, let us note that, as expected, the absolute availability of KETs significantly increases the probability for a region to create increasingly diversified industries. This holds true for both types of diversification patterns,

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[7] We used the *eoprobit* package available for Stata15.

[8] http://cercauniversita.cineca.it/php5/docenti/cerca.php

although the estimated coefficient of *KETs-Pat* in the *Tech-Space-Div* case is higher than that related to the *Space-Tech-Div* case.

Interestingly, the endowment of non-KETs technologies reduces the regional capacity of diversifying with respect to both the diversification patterns. This suggests that the basket of knowledge domains to be recombined in the Italian provinces is presumably large enough at 2004, to have presumably reached a saturation-dynamics, which contrast further diversification episodes with the assumed progressive scale of diversity. In the light of this last result, it becomes interesting to consider whether the provincial endowment of KETs is large enough with respect to that of non-KETs knowledge it could help recombine, to make their combinatory operation capable to favor diversification. This occurs only with respect to *Tech-Space-Div* (Column (3)), suggesting that KETs can be effective enough in recombining non-KETs to make the region capable of getting increasingly more diversified industries along the spatial dimension. On the contrary, the relative incidence of KETs over non-KETs does not help the region diversify according to a *Space-Tech-Div* pattern (Column (4)), that is, with the (sole) addition of a new niche development. This suggests that a stronger recombinatory leverage than KETs may be required to make the non-KETs of the region functional to such a diversification pattern.

Among the other regressors, we also find that the probability of unrelated diversification through a 'technology-upon-space' pattern increases with trade openness and bridging social capital, whereas it decreases the higher are unrelated variety, value added per capita, the number of inward greenfield FDI and human capital.[9] The probability of unrelated diversification through a 'space-upon-technology' pattern increases also with the rate of economic growth of the region and with the level of bonding social capital. No significant effect is found, instead, for the average knowledge complexity of the region.

Insert Table 5 about here

With respect to the same period of time, interesting results emerge by looking at the marginal effects that KETs have on the constitutive elements of our two ordered variables (Table 6), that is, in addition to no-diversification, common to both the diversification trajectories, replication and transplantation, in the specification with *Tech-Space-Diver*, and replication and exaptation, in the specification with *Space-*

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[9] We also re-estimate Equation 6 including the squared terms of VAPC, HK and FDI in order to detect potential non-linearities. For all of them, we find a positive and significant coefficient for the linear term and a negative and significant coefficient for the squared term, implying that their relationship with regional diversification can be non-linear.

Tech-Diver. First of all, let us notice that KETs apparently help regions to resist a possible inertia in diversifying, as they reduce the probability of non-diversifying in both the trajectories at stake. Second, KETs do also increase the region capacity of diversifying by replication, no matter in which ordered dependent variables they are fit. More importantly, the marginal effect of KETs appears greater on transplantation than on exaptation. As we have argued in Section 2.3, the role of KETs in spurring complementarity for fostering the recombination of existing activities is arguable harder to be effective when this recombination is expected to lead the region to have a new (national) niche.

When we consider the size of the marginal effects, Table 6 apparently suggests these are pretty small. For example, with respect to *Tech-Space-Diver*, a 1% increase in the KETs absolute endowment of a region is related to a 0.00015% increase in the probability to diversify through replication and of an additional 0.00004% of diversifying through transplantation. However, marginal effects are not negligible when we consider the distributions of *KETs-Pat* and of our dependent variables. The median regional endowment of the former is 2, whereas the 75th percentile corresponds to a value of 7. Therefore, passing from the 50th (i.e. the case of Ravenna or Trieste) to the 75th percentile (i.e. the case of Mantova) implies an increase in absolute KETs endowment of 250%, which, in turn, is related to an average 0.04% increase in the probability of replication and an additional 0.01% probability of transplantation. If, instead, we pass from the median to the 99th percentile (i.e. 603, as in the case of Milan), that corresponds to a 30050% increase in *KETs-Pat*, the corresponding increase in the probabilities of replication and transplantation are, respectively, 4.5% and 1.2%[10].

A similar argument applies to the case of *Space-Tech-Diver*. A 1% increase in *KETs-Pat* is associated to an average 0.00012% increase in the probability of replication and an additional average 0.00003% increase in exaptation. On the other hand, an increase of the absolute KETs endowment from the median value to the value of the 99th percentile is related to an average 3.6% increase in the probability of replication and an additional average 0.03% increase in the probability of exaptation. Similarly, increasing the relative KETs endowment from the 50th (0.036, as in Ravenna and Naples) to the 99th percentile (1.485, as in Catania) corresponds to an average 3.4% increase in the probability of replication and an additional average 0.93% increase in the probability of transplantation.

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[10] This means that the average probability of passing from a no-diversification state (i.e. non-entry) to unrelated diversification through transplantation is 6.7%.

Insert Table 6 about here

As the relative endowment of KETs does not appear to affect our second diversification trajectory, consisting of the addition of new niches development to a replication pattern, the rest of the analysis will be carried out with respect to the first trajectory, adding unrelatedness to replication. To start with, Table 7 shows the results of the extended ordered probit regression model, where we treat *KETs-Pat* as endogenous in the *Tech-Space-Diver* specification. In Column 1, we include the instrument (i.e. the stock of academic personnel working in Italian Universities and belonging to hard sciences) linearly. We find a highly statistically significant relation with our endogenous variable, but the estimated coefficient from the first-stage regression is negative. Therefore, in Column 2 we also included the squared term of the instrument, and we find that the relation with *KETS-Pat* follows an inverted-U shape. The very high value of the F statistic reveal that the instrument is very strong. With this new estimation setting, the coefficient of our KETs-Pat variables remains positive, statistically significant, and slightly higher than that found on Table 5. Our previous results thus appear robust with respect to the source of endogeneity that could make them potentially unreliable.

Insert Table 7 about here

Still with respect to *Tech-Space-Divers*, in Tables 8 and 9, we split the “total” regional endowment of KETs into that of the six typologies of KETs it comprehends, namely: advanced manufacturing technologies (AMT), advanced materials (ADV), biotechnology, nanoelectronics, nanotechnologies and photonics. Table 8 shows the results of the ordered probit regressions where the absolute endowment of each six technology enters separately in Equation 6, while Table 9 show the results of the relative endowments of KETs with respect to non-KETs.

Quite interestingly, the results we have obtained by retained their simultaneous presence appears to apply to certain kinds of KETs only. When their absolute endowment is considered (Table 8), all of the retained KETs help regions to get increasingly more diversified industries, apart from AMT and photonics. In the Italian context, the diversifying role of AMT and photonics appears reliant on that of the other KETs, at least in the trajectory we are considering.

When the relative endowment of KETs over non-KETs is instead considered, Table 9 shows that individual KETs do not drive *Tech-Space-Diver* apart from ADV and

Biotech. In other words, in the Italian context, ADV and Biotech are the only KETs capable to exert an “actual”, individual diversifying role (at stake).

Insert Table 8 about here

Insert Table 9 about here

Our last battery of results refers to the second period of our analysis, that is, 2008-2010. As we already said, with respect to this period, which coincides with the occurrence of a substantial economic crisis, for the country and a great part of the rest of the world, we observe only one of our two focal diversification trajectories, that is, *Tech-Space-Diver*. Indeed, not only not we have any case of saltation, as in the previous period, but of exaptation either. As expected, the adverse conjectural moment of the regional economies seems to inhibit their capacity of entering into new economic activities in terms of employment.

With respect to *Tech-Space-Diver*, Table 10 shows that, during the economic downturn, and differently from the previous period, the absolute KETs endowment does not affect the capability of Italian NUTS3 regions to diversify in unrelated industries, whereas the estimated coefficient of Non-KETs endowment is still negative, but weakly significant (see Column (1)). From Column (2), instead, we find that a higher relative endowment of KETs is negatively associated to the probability of the unrelated diversification at stake. In order to dig more in this result, in Column (3) we have added the squared value of *KETs/Non-KETs*. Quite interestingly, we find that the estimated coefficient of the linear term remains negative and statistically significant, while that of the squared term is positive and significant, revealing a potential U-shaped relationship with *Tech-Space-Diver*. Looking back at Table 4, we also note that the mean value of *KETs/Non-KETs* is lower in 2008-10 with respect to 2004-07: this is explained by a lower mean value of the numerator (*KETs-Pat*) and a higher mean value of the denominator (*Non-KETs-Pat*). In such a scenario, where the relative incidence of *KETs-Pat* is decreasing, and so does the entries of new industries, and where the risks of undertaking an unrelated diversification strategy are higher, regions require a minimum threshold of KETs-related patents in order to efficiently recombine their capabilities and generate new activities.

Insert Table 10 about here

5. Conclusions

In this paper, we have analyzed the drivers of regional diversification in Italian NUTS3 regions, by retaining both the place and path-dependence that can mark its unfolding. Drawing on the recombinant approach to diversification, we have focused on the recombinatory properties of KETs, on the basis of which we expect they could affect regional diversification at large. More precisely, we have maintained that, on the one hand, KETs could have a differential effect on different diversification patterns, on the other hand, that KETs could help regions to escape the eventual risk of lock-in that no-diversification and a pure replication strategy would entail. By extending the taxonomy put forward by Boschma et al. (2017), we have focused on two possible trajectories of an ‘ideal’ escaping transition from a “replicative” kind of diversification, subject to both path and spatial dependence. A first trajectory is represented by a “technology-upon-space” kind of diversification, in which regions pass through the “transplantation” of an existing regime in developing related activities. The second one is a “space-upon-technology” diversification, in which regions pass through an “exaptation” of a new niche by drawing on related capabilities. Still by referring to the recombinatory properties of KETs, we have argued they could help regions in creating progressively more diversified industries along both of the two trajectories.

Merging employment data from ISTAT and patent information from OECD-Regpat, we have estimated a series of ordered probit models, where the propensity of regions to generate new activities that are progressively less related to those already existing, is regressed against the absolute and relative KETs endowment, and on a series of characteristics capturing the degree of relatedness, complexity and development of regions.

The results of the estimates are in general supportive of our arguments, although they provide interesting nuances to their holding. First of all, we find that, before the economic crisis (2004-2007), regions that are more equipped with KETs, are also those more likely to undertake an ‘technology-upon-space’ diversification pattern, passing from the replication of existing activities to diversification through the transplantation of niches that are new to the region, but not to the world. The role of KETs is instead is weaker in the case of a ‘space-upon-technology’ diversification strategy, as their contribution in enabling the creation of new niches with respect to their national environment appears negligible. This picture changes substantially in the crisis period (2008-2010), during which ‘technology-upon-space’ diversification is the only occurring pattern. Indeed, the role of KETs in favoring this diversification trajectory appears contingent to the availability of a minimum endowment of them in the region. Results become even more nuances when individual KETs are considered instead of their total endowment. Indeed, the set of KETs that is capable to have a driving role of diversification irrespectively from the others reduces substantially and, in the case of Italy at least, reduces to that of advanced materials and biotech.

The results we have obtained have important implications in both academic and policy terms. In the former domain, we contribute to enlarge the still scanty evidence and theory about unrelated diversification. In policy terms, instead, we provide evidence on how KETs could be used by the policy-makers to allow regions to escape from lock-iness situations in which they might have followed by replicating their local capabilities.

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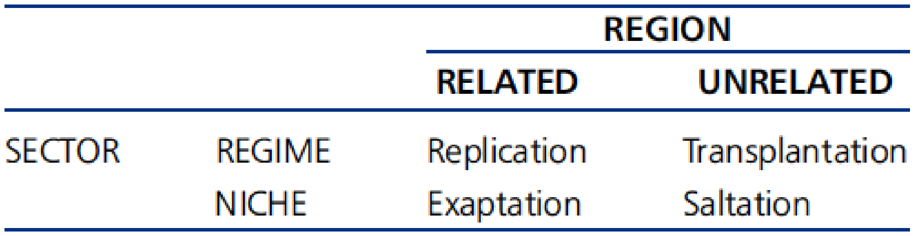
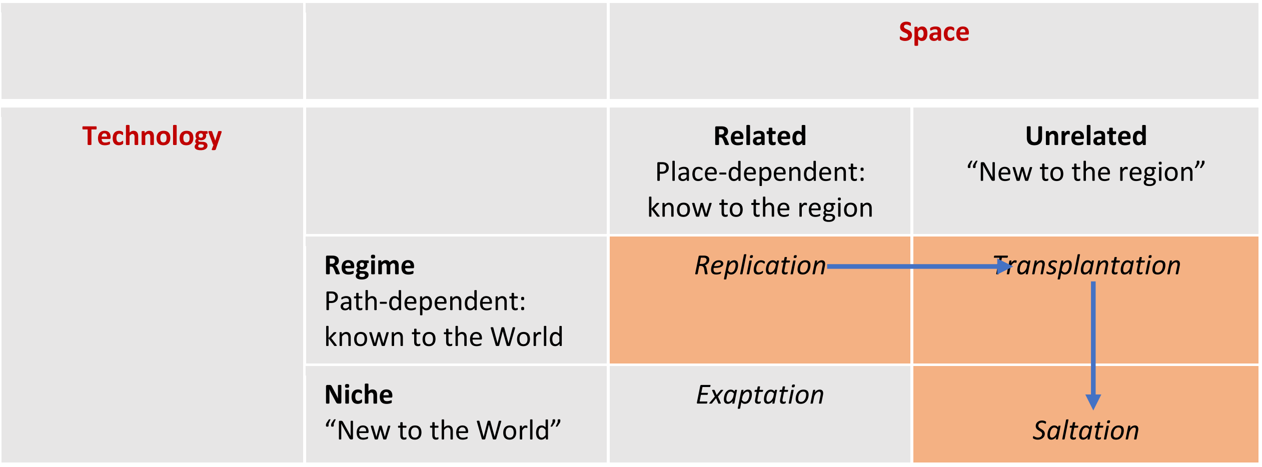
TABLES AND FIGURES

Table 1. Typology of regional diversification.

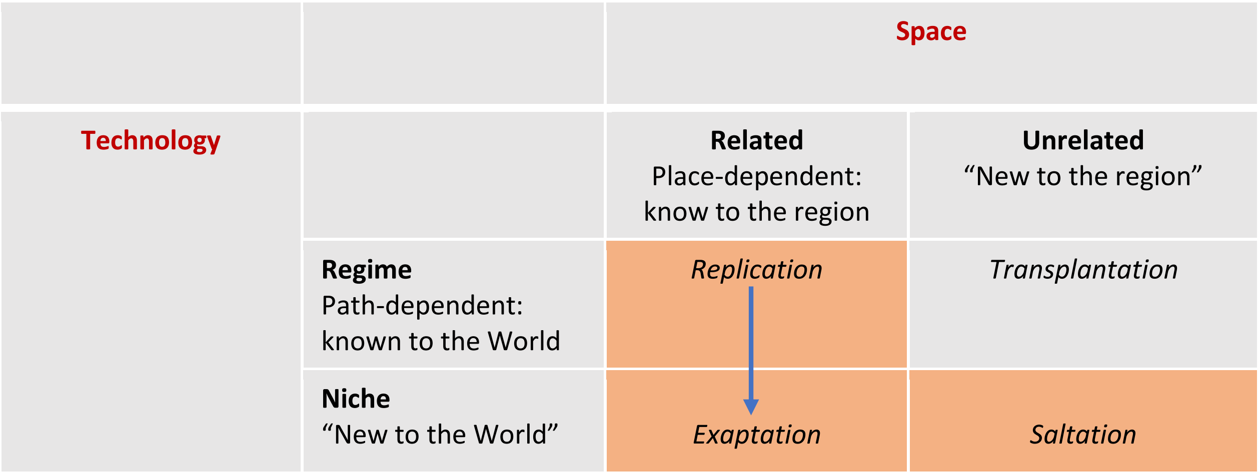


		REGION	
		RELATED	**UNRELATED**
SECTOR	REGIME	Replication	Transplantation
	NICHE	Exaptation	Saltation

Table 2 – Regional diversification patterns



		Space	
Technology		**Related** Place-dependent: know to the region	**Unrelated** “New to the region”
	Regime Path-dependent: known to the World	*Replication*	*Transplantation*
	Niche “New to the World”	*Exaptation*	*Saltation*



		Space	
Technology		**Related** Place-dependent: know to the region	**Unrelated** “New to the region”
	Regime Path-dependent: known to the World	*Replication*	*Transplantation*
	Niche “New to the World”	*Exaptation*	*Saltation*

Table 3 – Distribution of entries and regional diversification patterns

	2004-07		2008-10	
	N. of 5-dgt industries	%	N. of 5-dgt industries	%
entry	2,782	4.38	2,248	3.33
- *Replication*	*2,109*	*75.81*	*1,760*	*78.29*
- *Transplantation*	*522*	*18.76*	*488*	*21.71*
- *Exaptation*	*135*	*4.85*	*0*	*0.00*
- *Saltation*	*16*	*0.58*	*0*	*0.00*
Total obs.	63,449	100.0	67,485	100.0

Table 4- Summary statistics

Variable	Year	Mean	Std. dev.	Min	Max
KETs-Pat	2002-04	13.31	65.58	0	602.83
	2006-08	11.22	44.13	0	404.58
Non-KETs-Pat	2002-04	116.15	292.43	0.001	2432.24
	2006-08	126.35	292.57	0.333	2391.77
KETs/Non-KETs	2002-04	0.140	0.634	0	6.429
	2006-08	0.127	0.328	0	3.043
RV	2004	0.231	0.030	0.135	0.300
	2008	0.240	0.028	0.121	0.298
UV	2004	4.433	0.185	3.921	4.707
	2008	5.086	0.174	4.624	5.447
ECI	2004	-0.006	0.147	-0.374	0.337
	2008	-0.008	0.082	-0.217	0.175
HK	2001	0.323	0.034	0.240	0.451
FDI	2004	1.339	5.162	0	41
	2008	2.299	8.369	0	71
VAPC	2004	20614.09	7505.55	9260.69	75747.7
	2008	23086.64	5819.13	12548.95	35883.79
GROWTH	2001-04	0.091	0.053	-0.038	0.252
	2005-08	0.077	0.100	-0.098	0.667
POPDEN	2004	258.28	349.38	37.235	2603.31
	2008	267.62	355.83	38.938	2625.14
TRADE	2004	51.207	52.008	1.542	335.11
	2008	53.730	55.512	1.562	383.27
BOND SK	2003	0.447	0.259	-0.005	1
BRID SK	1999-2002	0.424	0.169	0.021	0.825

Table 5 – Ordered probit estimates (2004-07)

	Tech-Space-Diver		Space-Tech-Diver	
	(1)	(2)	(3)	(4)
KETs-Pat	0.00248***		0.00192***	
	(0.00068)		(0.00059)	
Non-KETs-Pat	-0.00054***		-0.00052***	
	(0.00015)		(0.000)	
KETs-Pat/Non-KETs-Pat		0.015**		0.010
		(0.006)		(0.007)
RV	-0.337	-0.333	-0.242	-0.272
	(0.531)	(0.560)	(0.427)	(0.465)
UV	-0.453***	-0.585***	-0.312***	-0.450***
	(0.108)	(0.103)	(0.105)	(0.101)
ECI	0.063	0.012	0.165*	0.093
	(0.120)	(0.126)	(0.095)	(0.104)
POPDEN	-0.000*	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
VAPC	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
GROWTH	0.301	0.350	0.412*	0.465**
	(0.249)	(0.255)	(0.222)	(0.224)
HK	-1.514**	-1.643**	-0.981	-1.066*
	(0.707)	(0.740)	(0.621)	(0.635)
TRADE	0.001***	0.002***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
FDI	-0.017***	-0.015**	-0.001	-0.004
	(0.006)	(0.006)	(0.005)	(0.003)
BOND SK	0.308**	0.169	0.333***	0.216*
	(0.140)	(0.137)	(0.121)	(0.112)
BRID SK	0.265*	0.339**	0.033	0.103
	(0.137)	(0.137)	(0.124)	(0.121)
Regional dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
N	63449	63449	63449	63449
Pseudo R^2	0.1642	0.1637	0.1413	0.1408
Mean VIF	4.19	3.59	4.19	3.59

Notes: all the estimates include also a constant term. Cluster (at NUTS3 region level)-robust standard errors in parentheses. *** p<0.01 ** p<0.05 * p<0.1.

Table 6. Average marginal effects

	Tech-Space-Diver		
	No-diversification	Replication	Transplantation
KETs-Pat	-.0001851***	0.0001456***	0.0000396***
Non-KETs-Pat	.0000401***	-0.0000315***	-0.000000858***
KETs-Pat/Non-KETs-Pat	-.0010831***	0.0008515**	0.0002316**
	Space-Tech-Diver		
	No-diversification	Replication	Exaptation
KETs-Pat	-.0001299***	0.0001209***	0.000000897***
Non-KETs-Pat	.0000357***	-0.0000333***	-0.000000247***

Table 7 – Extended ordered probit estimates, endogenous KETs (2004-07)

	Tech-Space-Diver	
	(1)	(2)
KETs-Pat	*0.0053***	*0.0028****
	(0.0021)	*(0.0009)*
Non-KETs-Pat	-0.001***	-0.001***
	(0.000)	(0.000)
RV	-0.248	-0.328
	(0.545)	(0.524)
UV	-0.345**	-0.440***
	(0.138)	(0.114)
ECI	0.071	0.064
	(0.121)	(0.119)
POPDEN	-0.000*	-0.000*
	(0.000)	(0.000)
VAPC	-0.000	-0.000**
	(0.000)	(0.000)
GROWTH	0.249	0.297
	(0.265)	(0.249)
HK	-0.880	-1.462**
	(0.808)	(0.732)
TRADE	0.001***	0.001***
	(0.000)	(0.000)
FDI	-0.032**	-0.018**
	(0.014)	(0.007)
BOND SK	0.534**	0.331**
	(0.219)	(0.162)
BRID SK	0.157	0.257*
	(0.176)	(0.142)
Regional dummies	Yes	Yes
Industry dummies	Yes	Yes
First-stage		
Hard science	-0.021***	0.014**
	(0.007)	(0.005)
Hard science^2		-0.000***
		(0.000)
Kleibergen-Paap F statistic	5892.9	20880.5
Hansen J statistic (p-value)		0.222
N	63449	63449

Notes: all the estimates include also a constant term. Cluster (at NUTS3 region level)-robust standard errors in parentheses. *** p<0.01 ** p<0.05 * p<0.1.

Table 8 – Ordered probit estimates, by single KET (2004-07)

	Tech-Space-Diver					
	(1)	(2)	(3)	(4)	(5)	(6)
AMT	0.005					
	(0.007)					
ADVANCED MATERIALS		0.005***				
		(0.001)				
BIOTECH			0.022***			
			(0.007)			
NANOELECTRONICS				0.011***		
				(0.002)		
NANOTECH					0.145***	
					(0.029)	
PHOTONICS						-0.002
						(0.004)
Non-KETs-Pat	-0.000**	-0.000***	-0.000**	-0.001***	-0.001***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
RV	-0.320	-0.247	-0.454	-0.374	-0.390	-0.317
	(0.550)	(0.543)	(0.516)	(0.526)	(0.515)	(0.552)
UV	-0.493***	-0.478***	-0.513***	-0.443***	-0.409***	-0.531***
	(0.113)	(0.104)	(0.105)	(0.105)	(0.107)	(0.110)
ECI	0.049	0.065	0.080	0.059	0.082	0.053
	(0.124)	(0.121)	(0.117)	(0.117)	(0.117)	(0.124)
POPDEN	-0.000*	-0.000*	-0.000	-0.000*	-0.000*	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VAPC	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GROWTH	0.312	0.329	0.369	0.229	0.224	0.307
	(0.257)	(0.252)	(0.243)	(0.246)	(0.243)	(0.253)
HK	-1.732**	-1.445**	-1.723**	-1.645**	-1.512**	-1.835**
	(0.715)	(0.720)	(0.705)	(0.675)	(0.684)	(0.720)
TRADE	0.002***	0.001***	0.002***	0.001***	0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	-0.008	-0.015**	-0.018**	-0.014**	-0.017***	-0.003
	(0.009)	(0.006)	(0.009)	(0.006)	(0.006)	(0.009)
BOND SK	0.217	0.287**	0.240*	0.286**	0.335**	0.149
	(0.145)	(0.138)	(0.135)	(0.133)	(0.135)	(0.144)
BRID SK	0.291**	0.288**	0.299**	0.233*	0.237*	0.312**
	(0.134)	(0.137)	(0.135)	(0.135)	(0.136)	(0.139)
Regional dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	63449	63449	63449	63449	63449	63449
Pseudo R^2	0.164	0.164	0.164	0.164	0.164	0.164

Notes: all the estimates include also a constant term. Cluster (at NUTS3 region level)-robust standard errors in parentheses. *** p<0.01 ** p<0.05 * p<0.1.

Table 9 – Ordered probit estimates, by single KET (2004-07)

	Tech-Space-Diver					
	(1)	(2)	(3)	(4)	(5)	(6)
AMT/Non-KETs	0.069					
	(0.066)					
ADV/Non-KETs		0.019^{***}				
		(0.006)				
BIOTECH/Non-KETs			0.538^{**}			
			(0.252)			
NANOEL/Non-KETs				0.004		
				(0.117)		
NANOTECH/Non-KETs					-77.439	
					(70.782)	
PHOTONICS/Non-KETs						-1.236
						(0.840)
RV	-0.347	-0.328	-0.353	-0.361	-0.299	-0.283
	(0.562)	(0.560)	(0.543)	(0.558)	(0.551)	(0.548)
UV	-0.579^{***}	-0.586^{***}	-0.577^{***}	-0.582^{***}	-0.592^{***}	-0.559^{***}
	(0.104)	(0.103)	(0.101)	(0.104)	(0.101)	(0.103)
ECI	0.008	0.014	0.040	0.004	0.015	0.027
	(0.127)	(0.126)	(0.121)	(0.128)	(0.124)	(0.125)
POPDEN	-0.000	-0.000	-0.000	-0.000	-0.000^{*}	-0.000^{*}
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VAPC	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000^{***}
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GROWTH	0.354	0.346	0.364	0.335	0.335	0.284
	(0.257)	(0.255)	(0.247)	(0.254)	(0.255)	(0.250)
HK	-1.659^{**}	-1.636^{**}	-1.672^{**}	-1.705^{**}	-1.671^{**}	-1.737^{**}
	(0.737)	(0.741)	(0.743)	(0.732)	(0.730)	(0.718)
TRADE	0.002^{***}	0.002^{***}	0.002^{***}	0.002^{***}	0.002^{***}	0.002^{***}
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	-0.015^{**}	-0.015^{**}	-0.015^{**}	-0.014^{**}	-0.005	-0.012^{**}
	(0.006)	(0.006)	(0.007)	(0.006)	(0.010)	(0.006)
BOND SK	0.172	0.169	0.177	0.163	0.125	0.194
	(0.137)	(0.137)	(0.138)	(0.137)	(0.142)	(0.139)
BRID SK	0.338^{**}	0.338^{**}	0.319^{**}	0.334^{**}	0.329^{**}	0.320^{**}
	(0.138)	(0.137)	(0.137)	(0.137)	(0.137)	(0.136)
Regional dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	63449	63449	63449	63449	63449	63449
Pseudo R^2	0.164	0.164	0.164	0.164	0.164	0.164

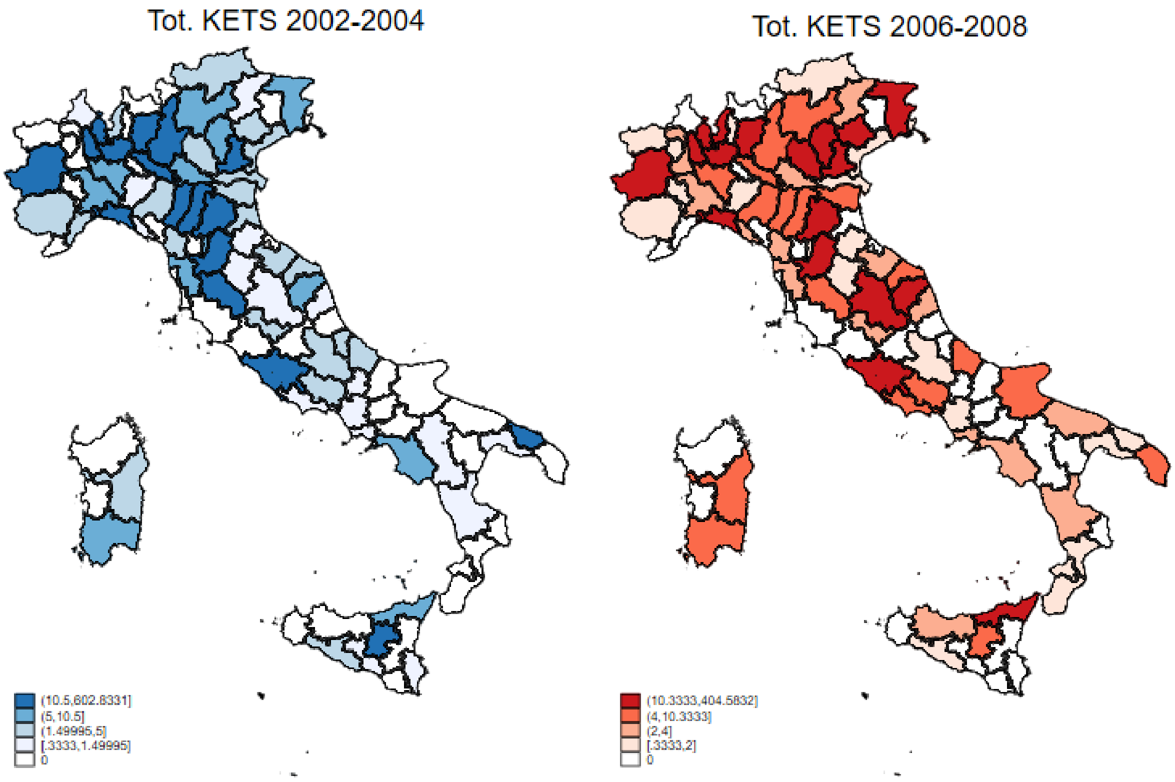
Notes: all the estimates include also a constant term. Cluster (at NUTS3 region level)-robust standard errors in parentheses. *** p<0.01 ** p<0.05 * p<0.1.

Table 10 – Ordered probit estimates (2008-10)

	Tech-Space-Diver		
	(1)	(2)	(3)
KETs-Pat	0.003		
	(0.002)		
Non-KETs-Pat	-0.000*		
	(0.000)		
KETs-Pat/Non-KETs-Pat		-0.098***	-0.264**
		(0.037)	(0.104)
KETs-Pat/Non-KETs-Pat^2			0.064*
			(0.035)
RV	1.369**	1.309**	1.225**
	(0.572)	(0.604)	(0.619)
UV	-0.477***	-0.548***	-0.544***
	(0.145)	(0.138)	(0.135)
ECI	0.224	0.140	0.176
	(0.341)	(0.334)	(0.329)
POPDEN	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
VAPC	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
GROWTH	0.276**	0.317**	0.308**
	(0.129)	(0.132)	(0.134)
HK	0.059	-0.045	-0.078
	(0.720)	(0.706)	(0.689)
TRADE	0.001**	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
FDI	-0.008	-0.006	-0.006
	(0.006)	(0.005)	(0.005)
BOND SK	0.332**	0.229	0.215
	(0.163)	(0.156)	(0.151)
BRID SK	0.167	0.250	0.252
	(0.201)	(0.194)	(0.191)
Regional dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
N	67485	67485	67485
Pseudo R^2	0.087	0.087	0.087

Notes: all the estimates include also a constant term. Cluster (at NUTS3 region level)-robust standard errors in parentheses. *** p<0.01 ** p<0.05 * p<0.1.

Figure 1 – The geography of KETs total endowment (KETs-Pat)

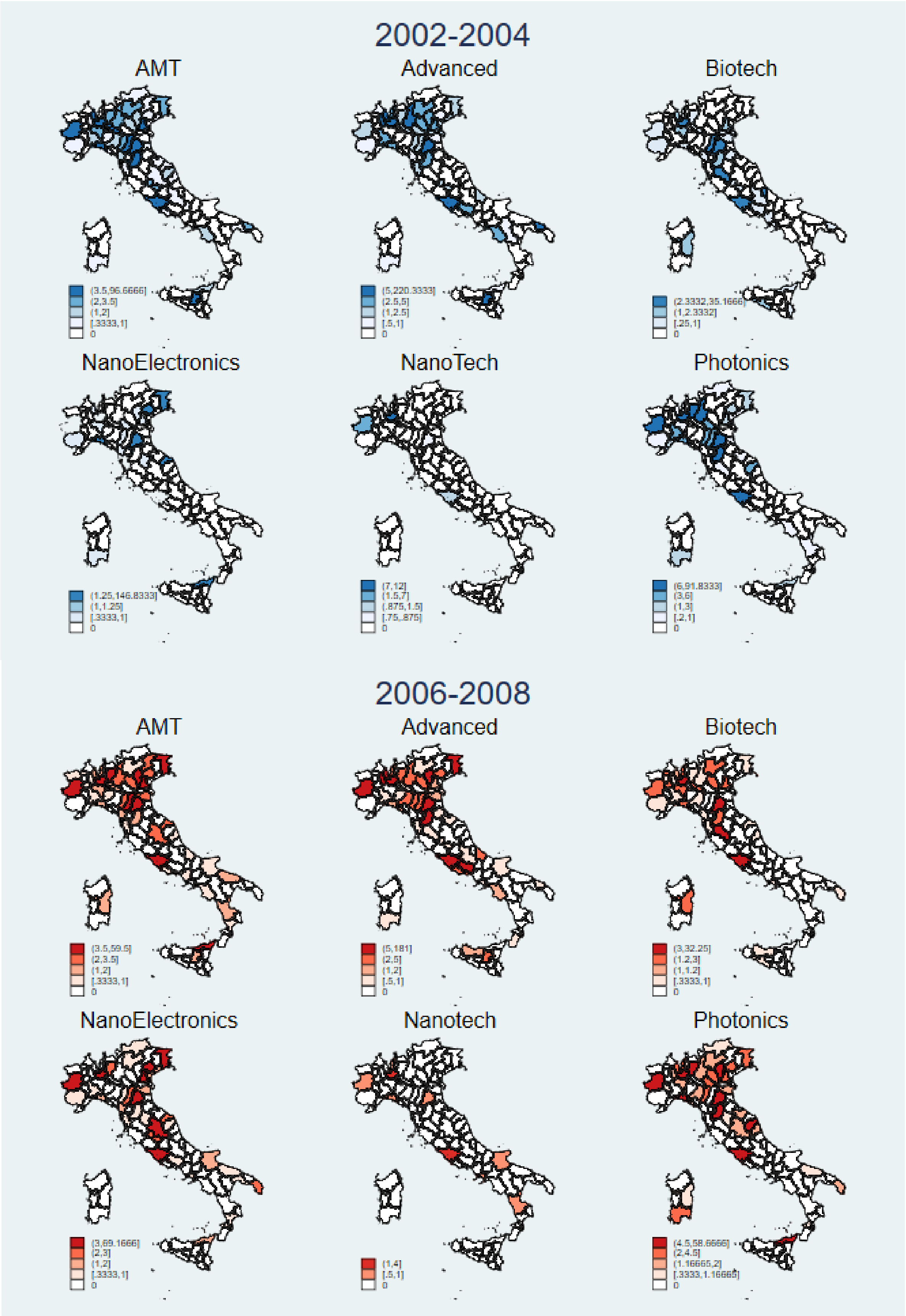


Tot. KETS 2002-2004

Tot. KETS 2006-2008

Source: author’s elaborations from OECD-Regpat data.

Figure 2 – The geography of the six KETs



Source: author’s elaborations from OECD-Regpat data.