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SEEDING PATTERNS:
THE SOURCES OF REGIONAL DIVERSIFICATION

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Abstract

Relatedness has been largely acknowledged as a major driver of regional diversification: new industries grow out of technologically related industries by means of combinatorial knowledge dynamics and branching processes. However, by emphasizing the role of firms and entrepreneurs in new path creation, evolutionary scholars have not only underplayed the role of extra-regional actors, linkages and networks, but also the role of national state strategies and wider political economic relations. The research seeks to advance our knowledge and evidence about regional industrial diversification by tackling specific gaps in the literature in three distinct but interdependent contributions. The first paper proposes a systematization of the debate on related vs. unrelated diversification, with a focus on the latter and its implications for uneven regional development and sustainability transitions. The second paper analyses the role of two sets of drivers, namely technological relatedness and innovation policies, on the emergence of new Revealed Technological Advantages in the United States (1981-2010), providing evidence for both drivers by means of econometric estimations. The third paper deploys the concept of «related variety», as formulated by Boschma (2005) and Frenken, van Oort and Verburg (2007), to verify if well-diversified and interdependent creative industries determine more pronounced local creative employment growth in the Italian provinces (2008-2010), with corroborating findings.

Introduction

How do regions diversify over time? This question lies at the core of a thriving debate within economic geography, especially in light of its evolutionary turn. However, this focus on regional diversification is not new to economic geography. Interest on how regions have managed, or failed, to develop new specializations gained quite a momentum in the late 1980s - two of the classic cases being the rise of the Silicon Valley (Saxenian, 1985; Markusen, Hall, & Glasmeier, 1986) or the nadir of the once-thriving Ruhr region (Grabher, 1993) - but these studies largely rested on anecdotal evidences and therefore were hardly generalizable (Boschma, 2017). The quest for a broader and systematic analysis has since being pursued as a mean to curb the diffusion of a serendipitous approach to regional diversification (Krugman, 1991), according to which the emergence of new industrial paths can be traced back to 'some seemingly trivial historical accident' (*ibidem*, p.35). While this may be the case in some instances, coeval scholars claimed that, in many other instances, contextual and causal processes could be clearly identified, insofar as spurred by 'local capabilities' (Maskell & Malmberg, 1999; Asheim & Isaksen, 1997) or driven by purposive agency (Storper, 1995; Puffert, 2000; Garud & Karnøe, 2001).

From the perspective of Evolutionary Economic Geography (EEG), regional diversification is largely based on the notions of path-dependence and relatedness, which entail that new industries in a region are likely to grow out of existing ones through spillover and branching processes (Martin & Sunley, 2006; Boschma and Frenken, 2011). By these means, new path creation can be seen as the outcome of endogenous development processes, such as the presence of a large number of innovative firms in technological related industries. Indeed, unrelated diversification does occur, though more rarely. In fact, recent evidence suggests that it usually requires very different capabilities than existing local activities and, hence, can be driven by actors who built up their capabilities elsewhere (migrants, multinationals) or, in some cases, be supported by state policies. This is particularly relevant for lagging regions, which are likely to be markedly policy-driven in the early stages of their development, as they rely not only on 'supply-side' knowledge dynamics, but also on structural shifts in the institutional structure and in the systems of production and consumption. At the same time, economic globalization increasingly interconnects industry actors and institutional structures in distant places, so that the emergence of new industries also depends on highly complex, multi-scalar networks.

The research developed here seeks to advance our knowledge and evidence about regional industrial diversification by tackling specific gaps in the literature in three distinct but interdependent contributions

The first paper proposes a systematization of the debate on related vs. unrelated diversification, in light of the debate undergoing in different strands of the literature within and across economic geography. It remarks a key finding in Evolutionary Economic Geography, that is the accumulating evidence on related diversification in regions, but it is mainly concerned with the sources and implications of unrelated diversification. It is claimed that the scope for unrelated diversification considerably varies between regions and is narrower for lagging and peripheral ones. Accordingly, unrelated diversification is depicted as deeply embroiled with the broader question of uneven regional development, which calls for an active role of policymakers. A similar theoretical proposition is then advanced with respect to sustainability transitions, where unrelated diversification is eligible to undermine the detrimental role played by dominant technological regimes.

The second paper develops a measure of *regional capability match* to determine the degree of relatedness between an industry and a region's overall industry mix, using patent data. Thereafter, it employs this index to quantify the impact of relatedness on the acquisition of a new Revealed Technological Advantage (RTA) in a major patent class for 643 4-digit IPC classes and for the 50 United States (plus District of Columbia) over a period of more than 30 years, in line with the pioneering work proposed by Rigby (2015). Secondly, it validates the hypothesis that supply-side innovation policies (Mazzucato, 2013), by means of R&D subsidies, have a measurable impact on the ability of regions to diversify.

The third paper deploys the concept of «related variety», as formulated by Boschma (2005) and Frenken, van Oort and Verburg (2007), to verify if well-diversified and interdependent creative industries determine more pronounced local creative employment growth. A pooled OLS panel model was estimated for 73 Italian provinces (2008-2010), using the total amount of creative workers as dependent variable and the variety indexes as the main regressors. The results are mostly consistent with the initial hypothesis: related variety, in terms of complementarity between sectors, has a positive and significant effect on regional creative employment growth.

The project tracks diachronically the evolution of the debate undergoing in EEG since the late 2000s, along the continuum *related variety - relatedness*. As outlined in the first paper, related variety has been robustly documented in the literature as a key driver of regional development, as it entails a level of cognitive proximity that enables effective knowledge spillovers between sectors. As a result, the concept of related variety provided the theoretical and analytical framework needed to overcome the thorny question of whether localization *or* urbanization economies bring greater benefits to regional growth. However, this framework also introduced a new dichotomy between related and unrelated variety, where the latter still represents a critical asset for regional economies on at least two grounds: it is expected to be conducive of higher rates of breakthrough innovation (Castaldi, Frenken, & Los, 2015) and it provides local economies with the capability to absorb sector-specific shocks, which is usually referred to as *portfolio effect* (Boschma & Iammarino, 2009). It is precisely this kind of analysis that has been carried out in the third paper, with respect to a specific set of *creative industries*. In the long run, related variety is also a major input for regional diversification: new industries branch out of existing ones. This focal shift marks a departure from a static treatment of diversification (how diversified is a region?) to a dynamic one (by how much did the portfolio of local economic activities change?), which calls for new conceptual and analytical tools. Entropy measures, employed to detect the amount of related or unrelated variety within a local economy, give way to cosine distances and relatedness indexes, as the novel scope is to determine whether entries and exits of industries in a region are affected by the degree of relatedness with other industries in the region (Neffke, Hartog, Boschma, & Henning, 2018). As such, the most viable research strategy implies measuring the relatedness between a specific industry and the region's overall industry mix, and tracking the structural change of regional economies over long spans of time. However, while related diversification has received vast attention by scholars since the seminal contribution of Neffke, Henning & Boschma (2011), empirical assessment of how and why unrelated diversification occurs remains rather scant, as outlined in the first paper. Following these premises, the second paper aims at exploring the role of relatedness as driver of regional diversification processes in the United States and offers a broader approach that consider state-supported forms of new path development.

1. THE SOURCES OF UNRELATED DIVERSIFICATION AND ITS IMPLICATIONS FOR UNEVEN REGIONAL DEVELOPMENT AND SUSTAINABILITY TRANSITIONS

by ANDREA SIMONE

ABSTRACT

The paper proposes a systematization of the debate on related vs. unrelated diversification, in light of the debate undergoing in different strands of literature within and across economic geography. It remarks a key finding in Evolutionary Economic Geography, that is the accumulating evidence on related diversification in regions, but it is mainly concerned with the sources and implications of unrelated diversification. It is claimed that the scope for unrelated diversification considerably varies between regions and is narrower for lagging and peripheral ones. Accordingly, unrelated diversification is depicted as deeply embroiled with the broader question of uneven regional development, which calls for an active role of policymakers. A similar theoretical proposition is then advanced with respect to sustainability transitions, where unrelated diversification is eligible to undermine the detrimental role played by dominant technological regimes.

KEYWORDS: unrelated diversification, uneven development, sustainability transition

1.1 Introduction

In recent times, an increasing strand of literature, in geography and related disciplines, has tackled the question of how regions diversify into new industries or technologies. Regions face a constant pressure to renew or broaden their industrial base as a way to escape stagnation and decline. And this has led to a search for conditions and mechanisms that trigger long-term regional industrial change.

The importation of the concept of path dependence into economic geography has significantly enhanced our understanding of regional diversification, suggesting that 'the pre-existing industrial structure of a region or locality does have an influence of whether a particular new industry develops there' (Martin, 2010, p. 6). According to this view, 'the economic landscape of regions inherits the legacy of its own past' (Martin & Sunley, 2006, p. 408) and sets the possibilities for further diversification, which will occur in historically sequential patterns of activities. However, these processes can gradually give rise to a progressive ‘inflexibility’ or ‘lock-in” of the system into a dominant technology or a particular spatial concentration of industry (Arthur, 1989). The downturn of car manufacturing in Detroit is a strong reminder of how potentially devastating could be the decline of an economy’s dominant economic specialization. Lock-in isn’t, indeed, an inevitable outcome, but the reasons why some regional economies seem able to avoid this danger (by moving into new productive fields), while others don’t, are widely debated.

Drawing insights from evolutionary economics (Castaldi & Dosi, 2006), Martin and Sunley (2006) suggested five mechanisms of regional ‘de-locking’, i.e. ways in which regions can escape negative lock-in: indigenous creation, meaning the emergence of new industries without technological antecedents; heterogeneity, insofar as the evolutionary pattern promotes spillovers and cross-fertilization across related sectors; transplantation, that refers to the importation of new industries, technologies and organizational forms from elsewhere; diversification into related or derived fields; and upgrading and enhancement of existing industries, through the introduction of novel technologies, products or services.

This theoretical framework has spawned a burgeoning scholarly work, with three of the abovementioned mechanisms, namely diversification, transplantation and indigenous creation, gathering the most meaningful evidence. Remarkably, Evolutionary Economic Geography (EEG) research has devoted a great deal of attention on related diversification, seizing on the concept of branching (Frenken & Boschma, 2007) as a key ingredient to depict local industry formation. Several studies have confirmed the significance of relatedness as a key driver of regional diversification, despite differences in the measures of relatedness, scales of analysis and time periods covered (see, e.g., Hidalgo, Klinger, Barabasi, & Hausmann, 2007; Neffke, Henning, & Boschma 2011; Neffke & Henning, 2013; Tanner, 2014; Essletzbichler, 2015; Rigby, 2015; Boschma, 2017; He, Yan, & Rigby, 2018). Most notably, these studies largely deploy econometric analyses, investigating several regions simultaneously instead of focusing on only one case study, thus allowing for a generalization of the results.

The same studies show that unrelated diversification also occurs, though more rarely (Boschma, 2017). It is of no wonder that unrelated diversification is often described as a more exceptional event, as it is usually underpinned by breakthrough, new-to-market innovations, but this is precisely why it is considered to be associated with a long-lasting competitive advantage for regions (Boschma & Frenken, 2015). Conversely, regions over-relying on branching process could actually be trapped in path exhaustion (Isaksen, 2014) and their scope for escape from ‘lock-in’ could narrow. So, a crucial question is whether regions can continue to rely on related diversification to sustain their long-term growth, or whether they need to diversify in unrelated activities to offset the risk of path exhaustion. As a result, later research has been investigating the conditions that make regions more apt to diversify into unrelated activities. Import spillover (Andersson, Bjerke, & Karlsson, 2013), institutions (Boschma & Capone, 2015), type of regions (Xiao, Boschma, &

Andersson, 2018), economic level of countries (Petralia, Balland, & Morrison, 2017), inter alia, seem eligible to influence processes of unrelated diversification, but systematic evidence is still missing.

Besides its implication for regional growth, another central question for scholars is whether unrelated diversification should stem from endogenously generated change or be triggered by exogenous stimuli. In this regard, the concept of unrelated diversification is mostly compoundable with those of indigenous creation and transplantation, which have been subjected to preliminary scrutiny, both theoretical and empirical, by other strands of literature. Notably, the literature on 'path creation' (Garud, Kumaraswamy, & Karnoe, 2010) has stressed the importance of extra-regional sources of new path development and the multi-scalar interrelatedness and embeddedness of firms (see, e.g., Isaksen & Trippl, 2014; Binz, Truffer, & Coenen, 2016; Trippl, Grillitsch, & Isaksen, 2018). However, this question has further, more normative, implications.

On the one hand, a narrow model of endogenous diversification is particularly challenging for lagging regions, which often have lower endowments of resources and face structural and institutional failures in their innovation system. This perspective has been extensively explored by the Geographical Political Economy (GPE), which provides an integrated understanding of the broader processes and actors that shape path creation and its roots within the wider dynamics of capital accumulation and uneven regional development (MacKinnon, Cumbers, Birch, Pike, & McMaster, 2009; Dawley, MacKinnon, Cumbers, & Pike, 2015; Grillitsch & Sotarauta, 2018). On the other hand, endogenous diversification would appear to favour those regions that are in a better position to face grand societal challenges, such as climate change, ageing societies and food security (Coenen, Hansen, & Rekers, 2015), because their innovation systems are more related and/or less hostile to the radical novelties needed to address those challenges. In this respect, Transition Studies have devoted much effort to the more normative objective of improving societal systems in order to comply with conditions of sustainability (Geels & Raven, 2006; Truffer & Coenen, 2012; Verbong & Geels, 2012). Recent contributions have offered a complementary perspective on new industrial pathways, framing regional diversification as a process of resource mobilization and alignment (Binz, Harris-Lovett, Kiparsky, Sdlak, & Truffer, 2016) with a strong emphasis on 'entrepreneurial experimentation' and the concept of 'niche' (Coenen, Raven, & Verbong, 2010).

In light of this discussion, the aims of this article are to offer a brief overview of the main studies on regional diversification and support recent work that calls for a broader theoretical framework to regional diversification (Boschma, 2017; Boschma, Coenen, Frenken, & Truffer, 2017). The paper is structured as follows. The next section presents a critical review of the state of the art in EEG research about the dialectical juxtaposition of related and unrelated diversification. The third section tackles specific gaps in EEG literature concerning unrelated diversification and connects them to ideas from other sub-fields in economic geography. The fourth and fifth sections identify research areas that push economic geographers and policymakers to consider more normative questions of regional convergence and sustainability transitions, with a specific focus on green innovation. The sixth section concludes.

1.2 Relatedness and Regional Diversification

A major assumption about how regions diversify in new industries is the idea that variety is the key to novelty (Martin & Sunley, 2006). Under this assumption, the industrial diversity within a region is conducive to higher rates of innovation by means of "Jacobs externalities" among industries (Jacobs, 1969). But a similar argument holds in the case of firms competing in the same industry, as they are forced to innovate to gain competitive advantage over the others, thus providing a short-burst of fast regional growth (the so-called 'Red Queen hypothesis', see e.g. Martin & Sunley, 2006; Essletzbichler, 2012). Following Glaeser, Kallal, Scheinkman and Shleifer (1992), many scholars have tested whether regions benefit more from diversification or specialization, but there has been conflicting evidence for both hypotheses (De Groot, Poot, & Smit, 2009). Indeed, a possible reason for the weak evidence on Jacobs' externalities is that many technologies and/or services cannot be meaningfully combined (Schumpeter, 1912), since effective learning requires cognitive proximity between sectors (Boschma, 2005). Frenken, van Oort and Verburg (2007) proposed a more accurate definition of Jacobsian externalities, that distinguishes between 'related variety', which occurs when there are complementarities among sectors in terms of shared competences, and 'unrelated variety', which covers sectors that do not share complementary competences. Related variety seems to fit better with the idea that knowledge can actually spill over from one firm to another: any transfer of knowledge, in this guise, is likely to occur only when there is a technological proximity between the two firms. The evidence gathered on the positive correlation between related variety and regional growth has been highly corroborative (Essletzbichler, 2007; Quatraro, 2010; Bishop & Gripaios, 2010).

Frenken and Boschma (2007) depicted local industry formation as a branching process, where new industries emerge by means of spinoffs or breakaways from incumbents in adjacent fields, from which they draw and combine local capabilities. This is the case when a region diversifies from motorcycles to cars, for instance, as the two industries share similar practices and technologies. Therefore, the more related is the variety to a new potential industry in a region, the higher is the likelihood for that industry to emerge in the region.

This branching phenomenon received a first scrutiny at country level by Hidalgo, Klinger, Barabasi and Hausmann (2007), who found that countries tend to move through the 'product space' by developing products that are 'related' to those they had previously exported. The product space measures the relatedness between products on the basis of the frequency of co-occurrence of products in the export portfolios of countries. Hence, two products are considered ‘related’ if many countries show a revealed comparative advantage in both sectors, as this would reflect the fact that the two products require similar capabilities.

Indeed, several studies have confirmed the predominance of related diversification, irrespective of whether the spatial units of analysis are countries (e.g. Hausmann & Klinger, 2007; Petralia, Balland, & Morrison, 2017), regions (e.g. Van den Berge & Weterings, 2014; Tanner, 2014; He, Yan, & Rigby, 2018), or cities (e.g. Boschma, Balland, & Kogler, 2014; Essletzbichler, 2015; Rigby, 2015). However, the vast majority of the literature has focused on the subnational scale. One reason for this is that innovation is characterized by strong distance decay effects of knowledge spillovers that result in geographically localized search and adaptation processes further guided by local institutions in particular directions (Essletzbichler, 2012). Another reason is that, at the subnational level, issues related to diversification and potential consequences of industries’ decline are more pronounced. Indeed, local economies, such as cities or regions, are often more specialized than countries as a whole. Consequently, they depend more on one or several industries, firms or activities (Xiao et al., 2018).

Relatedness proves to be a meaningful driver of regional diversification but to test such relation is challenging. Scholars have employed different measures of inter-industry relatedness. A first strategy assumes relatedness among different industries when they co-occur in the same portfolio of products (at the level of export or production), thus reflecting apparent economies of scope (Neffke & Henning, 2013). This is a widely used approach among scholars (see, e.g., Hidalgo et al., 2007; Bryce and Winter, 2009). Most notably, Neffke et al. (2011) employed co-occurrence analysis at the plant level, so that products are considered related when requiring similar skills or machines. Their long-term analysis of 70 Swedish regions (1969-2002) confirmed that entries and exits of industries in a region were affected by the degree of relatedness with the pre-existing industries in that region. A similar logic, but with export data, has been applied by Boschma, Minondo and Navarro (2013) for 50 Spanish regions in 1988-2008.

A second strategy for measuring relatedness uses resource-based indicators. Here, the goal is detecting similarities among the resources employed in different industries, such as commodity flows, human capital and technological resources (Fan and Lang, 2000; Breschi, Lissoni, & Malerba, 2003). The technological relatedness measure, specifically, is based on the co-occurrence of technology classes in patent documents: when two technologies classes co-occur in the same patent document over again, it reflects the fact that they are technologically related. Rigby (2015) deployed this measure to test whether technologies related to pre-existing industries in a US metropolitan region had a higher probability to enter that region. The findings provided robust evidence of related technological diversification for the period 1975-2005, and this approach has been adopted by several other studies (see, e.g., Boschma, Balland, & Kogler, 2015; Van den Berge & Weterings, 2014; Heimericks & Boschma, 2014). Under the same logic, measures of occupational or skill relatedness have also been employed (Muneepeerakul, Lobo, Shutters, Gomez-Lievano, & Qubbaj, 2013; Neffke, Hartog, Boschma, & Henning, 2018), delivering similar conclusions.

On a less positive note, EEG literature has vastly relied on 'capabilities' as 'an umbrella concept for local assets' (Boschma, 2017, p.353), building on this powerful though slippery dimension to derive a generalized theory of relatedness, notwithstanding the substantial differences existing among regions. This comes with two main epistemological shortcomings: an opaque and generic measurement of capabilities and the relative neglect of the role of agency in the process of regional diversification. As Boschma (2017) pointed out with respect to the problem of measurement, relatedness among different capabilities have often been couched in terms of a symmetric phenomenon, but this might not be the case in many instances. For example, computer hardware skills may be relevant for the software industry, but software skills may be less valuable to the computer industry. So, asymmetry in relatedness needs to be considered and might help gathering new insights on regional diversification. Moreover, relatedness tends to be portrayed in terms of both similarity and complementarity, even though the two terms have different implications (Makri, Hitt, & Lane, 2010), and just few studies adopt narrower conceptualizations (Breschi et al., 2003; Broekel & Brachert, 2015; Neffke et al., 2011). Finally, studies have mainly used a universal global measure of relatedness, notwithstanding that contextual differences might exist among regions in the way activities are related (Boschma, 2017).

Furthermore, this spotlight on local capabilities overshadows the role of human agency in driving regional diversification. Scholars have seldom incorporated a micro-perspective to understand which types of firms and individuals actually trigger the emergence of new specializations in a region. Most notably, Klepper (2007) showed that entrepreneurs or incumbents with a background in related industries have a decisive role in the early industry formation. Other studies focused on the role of multinational enterprises (MNEs) or transnational entrepreneurs (Crescenzi, Gagliardi, & Iammarino, 2015; Iammarino & McCann, 2013; Vale & Carvalho, 2013), but this micro-foundation is mainly limited to economic actors. Public agencies, like universities, and other institutional actors have been largely neglected by the bulk of EEG literature.

In sum, related diversification is found to be a dominant pattern in regions, and this is confirmed by several analyses that adopt different methodological approaches. Diversification in regions is a deeply uncertain process that can be reduced by relying on existing local capabilities when diversifying into new activities.

Nevertheless, unrelated diversification also occurs, though less frequently, as it requires completely new capabilities and is consequently risky and expensive (Saviotti & Frenken, 2008). Scholars have started investigating the conditions that make regions more likely to diversify into unrelated activities, but a full account of the enabling or constraining factors for unrelated diversification is still undergoing in the EEG literature.

1.3 The Sources of Unrelated Diversification

Unrelated diversification occurs when a region develops a new activity requiring very different capabilities than existing local activities. This concept fits well within a generalized Schumpeterian framework, which considers radical innovations to be successful new combinations of previously unrelated domains (Schumpeter, 1912; Dosi, 1982). Studies on regional diversification show that unrelated variety is a rather exceptional event, since it entails a more uncertain and risky process. For instance, regions specialized in aerospace will hardly diversify into pharmaceuticals, as both activities are not related: there is a large distance between their underlying capability bases. Nevertheless, the principle of technological relatedness alone hasn't always proved sufficient to explain the logics of regional diversification. Some regions do indeed appear to be able to escape lock-in by establishing new industrial sectors that have no technological predecessors or antecedents. Martin and Sunley (2006) referred to this source of new path as 'indigenous creation', whose key determinants were identified, inter alia, in the presence of large firms with vast supply networks (Lazerson & Lorenzoni, 1999), the role of research institutions, or the ability of regions to retain/attract skilled and educated labour forces (Florida, 2002; Glaeser, 2005). A key question raised here is whether regions with 'loose network structures' (Martin & Sunley, 2006, p. 420) are better equipped to radically change their industrial basis rather than regions with strongly tied networks. Indeed, production networks with strong relationships within nodes are less likely to recombine previously unconnected technologies, because their scope for cross-fertilization is narrower. This is in line with Jacobs' argument that cities with many different industries would experience more innovation as knowledge exchange by people with different backgrounds would lead to more new products and processes (Jacobs, 1969). Therefore, regions exhibiting weaker specialization and/or higher degree of unrelated variety could be more apt to deliver radical innovations. Following this line of inquiry, Castaldi, Frenken and Los (2015) found that unrelated variety is associated with higher rates of breakthrough innovation in US, while incremental innovation is mainly associated with related variety.

In the rare cases that recombination innovations between unrelated technologies or services succeed, they become related (Desrochers & Leppälä, 2011). A vivid example is the self-driving car that emerges from new combinations of technology fields in automotives, sensor-based safety systems, communication and high-resolution mapping that were not previously combined. This recombinant approach has been adopted in studies on research collaborations and technical alliances (Boschma & Frenken, 2009a; Gilsing, Nooteboom, Vanhaverbeke, Duysters, & Van den Oord, 2008), but has not yet been applied to the study of regional diversification.

Evolutionary scholars have only recently started investigating the role of regional and national institutions in unrelated diversification processes. This represents a pivotal turn in the evolutionary literature, which originally conceived of institutions as 'orthogonal' to firms and thus constituting a separate 'explanans' (Boschma & Frenken, 2009b). While this 'methodological individualism' of EEG (MacKinnon, Cumbers, Pike, & Birch, 2007) keeps the research program manageable, it may run the risk of bracketing out important drivers of evolution from the outset and becoming too firm-centered in its analysis (Essletzbichler, 2012). At the regional level, Cortinovis, Xiao, Boschma, and van Oort (2017) found that bridging social capital (as opposed to bonding social capital) is an enabling factor for regional diversification in the EU, especially where formal institutions are weak (Rodríguez-Pose, 2013). The assumption is that diversification requires combinations between different activities that is facilitated by social capital that can bridge different social groups. Another enabling factor at regional level is the presence of key enabling technologies (KETs), which strengthens the ability of regions to diversify into more unrelated technologies (Montresor & Quatraro, 2015). At the national/macro level and within a 'varieties of capitalism' framework (Hall & Soskice, 2001), Boschma & Capone (2015) found that liberal market institutions are positively correlated with unrelated diversification, in contrast to institutions associated with coordinated market economies that make countries rely more on related diversification. Also the economic level of countries could play a role in this scenario, as Petralia, Balland, and Morrison (2017) showed, with high-income countries showing a higher tendency to diversify into unrelated technologies as compared to low-income ones. These evidences come close to those gathered at regional level by Xiao et al. (2018) that tested whether the influence of industry relatedness on diversification differs across regions with different economic and industrial structures, distinguishing between core knowledge, manufacturing and peripheral regions. The formers seem more capable to break from their past by developing new specializations, as their innovation capacity allows them to rely less on relatedness as driver of diversification.

Nevertheless, this emerging literature on unrelated diversification is still fragmented and underdeveloped, often singling out one single driving factor, and not providing a comprehensive theoretical framework. Besides, the EEG literature has tended to conceive regional diversification as a largely endogenous process (MacKinnon, Dawley, Pike, & Cumbers, 2019) whereas there is increasing evidence that more unrelated diversification comes from the outside. So, scholars have started questioning whether unrelated diversification should stem from endogenously generated change or be triggered by exogenous stimuli. This question goes back to the very inception of the path dependence debate, i.e. regional lock-in should be viewed as a 'conditional equilibrium' established by prior path-dependent processes and subsequently redefined by endogenous forces (Setterfield, 1997), or as a 'punctuated equilibrium' where only exogenous triggers enable system-wrenching changes (David, 2001). Indeed, among the five mechanisms of regional path creation, Martin and Sunley (2006) explicitly acknowledge the possibility of exogenous sources of new path development, referring to 'transplantation' as 'the importation and diffusion of new technologies, industries, firms or institutional arrangements, from outside' (ibidem, p. 422). According to this definition, transplantation covers a broad spectrum of phenomena and, consequently, scholarly work, ranging from research about global value chains (GVCs) (Gereffi, Humphrey, & Sturgeon, 2005) and global production networks (GPNs) (Coe, Dicken, & Hess, 2008), to the literature on the trans-scalar geography of knowledge linkages (Bathelt, Malmberg, & Maskell, 2004). However, this literature has been, so far, mainly disconnected to the work on new regional path development and lacks of a proper systematization in this regard. A similar issue is analysed in the expanding literature on new growth paths (Garud et al., 2010), which focus on path renewal (or branching) and new path creation (or development), the second reflecting unrelated diversification. In a recent work, Trippl et al. (2018) distinguish between two main exogenous sources: the arrival of new actors in the region, by means of individuals and/or firms, and extra-regional knowledge linkages.

The inflow of new firms may primarily occur through the relocation of firms or subsidiaries thereof. Neffke et al. (2016) showed that new plants from outside are actually more conducive to unrelated diversification in the region as compared to start-ups or incumbents, as the formers can rely on a relatively patient capital from their holding company as well as abundant resources that do not exist in the region. Alternatively, the inflow can also originate through foreign direct investments (FDIs), by means of takeover or merger of local firms, but their impact to regional evolution is controversial (MacKinnon, 2011). The inflow of individuals is also a major source of incoming knowledge and has been subjected to detailed scrutiny by scholars, especially with respect to the migration of highly skilled people (Kapur & McHale, 2005; Bahar & Rapoport, 2018). Saxenian (2006) is one of the few studies that have explicitly explored the link between the inflow of new knowledge through mobile individuals and new path creation. In her work on the 'new argonauts' (ibidem), she showed that successful return migrants from the Silicon Valley have triggered the rise of ICT industries in Asian countries, thus fuelling the launch of unrelated industrial opportunities in their home countries.

New development paths may also be supported through extra-regional knowledge flows, by means of formal (contract-based) or informal linkages, such as social networks between former colleagues (Agrawal, Cockburn, & McHale, 2006), communities of practice (Wenger, 1998) or epistemic communities (Amin & Roberts, 2008). In a case study of on-site water recycling in Beijing, Binz, Truffer, and Coenen (2016) showed that in the first phase of industry formation most of the key resources were imported from outside, and then gradually transformed to endogenous regional resources. Therefore, the way early actors mobilize and anchor key resources for industry formation from outside the region is pivotal for a new path development.

Finally, regions are not equally demanding or receptive of non-local knowledge, as they differ in their need and capacity to attract it and transform it into new development paths. Looking at different Regional Innovation Systems (RISs), Trippl et al. (2018) expect exogenous sources to be catalysed mainly by organizationally thick and diversified RISs (core regions), while old industrial areas and peripheral regions are unlikely to attract and absorb incoming opportunities. This line of inquiry leads to similar conclusions to those of Xiao et al. (2018) with respect to the differentiated role that relatedness plays in core versus peripheral regions and, therefore, their need of exogenous stimuli. The next section further stresses this point of analysis.

1.4 Unrelated Diversification and Uneven Regional Development

Notwithstanding recent works on peripheral regions, the bulk of scholarly work on regional diversification have so far neglected a proper assessment of the role of broader processes of uneven development and regional divergence/convergence (MacKinnon et al., 2019), and has been largely silent about policies and politics. In this regard, it is worth noting that path dependence and path creation are strongly related to the dynamics of capital accumulation and the underlying tension between fixity and flux in the economic landscape (Harvey, 1982; Massey, 1984; Smith, 1984). Accordingly, regional patterns of economic specialization and uneven development tend to be self-reinforcing and self-reproducing over long spans of time (Martin & Sunley, 2006), so that opportunities for new path creation considerably vary between regions, reflecting their position within wider spatial divisions of labour (Massey, 1995).

More specifically, by emphasizing the role of firms and entrepreneurs in new path creation, EEG scholars have not only underplayed the role of extra-regional actors, linkages and networks (Coe, 2011; MacKinnon, 2011), but also the role of national state strategies and wider political economic relations (Morgan, 2013). Indeed, ‘the policy agenda in EEG has remained largely implicit’ (Asheim, Brugge, Coenen, & Herstad, 2013, p.2) and has mainly built on the concept of relatedness, which have highly influenced the development of EU Smart Specialization Strategies (Foray, 2014; McCann & Ortega-Argilés, 2014). Most notably, the Constructing Regional Advantage (CRA) approach developed by EEG scholars has adopted a ‘contextual view’ of policy intervention, which is expected to assist regional branching by supporting new sectors that have their roots in the regional knowledge base and technological field (Boschma, 2013). While the precise implications for operational policies remain vague, these perspectives suggest that successful policy outcomes can be achieved by stimulating the mechanisms of transferring knowledge among related sectors and activities, described by Cooke (2010) as “stimulating transversality”. The policy prescription of stimulating related diversification is compelling on several grounds, since relatedness has proven to be a dominant driver in regional development. However, by ignoring the structural and extra-regional condition of uneven development, these policy prescriptions may be insufficient or, worst, they may favour further prosperous regions endowed with a plethora of endogenous assets and overlook lagging regions, whose ability to diversify are inherently weaker (Isaksen, 2014). Alternatively, supra-regional policies could exert downward causal pressure directly on a region's mix of firms, industries, social networks, and institutions, shifting the direction of change in new unrelated ways. This would entail broadening the 'contextual view' proposed by the CRA approach by stimulating unrelatedness in those places where the ability for a successful related diversification is constrained: namely the old industrial areas (OIAs) and the peripheral regions (Trippl et al., 2018).

The OIAs, which are organizationally thick but strongly specialised in one or few clusters, could experience rigidity in the later stages of their development and be 'myopic' to new opportunities that lay beyond existing growth paths (Maskell and Malmberg, 2007). Due to the dominance of a few clusters, the degree of intra-regional related variety is low and only few opportunities for combining or recombining diverse knowledge bases at the regional scale exist (Boschma, 2015). So, they are exposed to a higher risk of path exhaustion (Isakesen, 2014) and technological sclerosis (Steil, Victor, & Nelson, 2002).

On the other hand, peripheral regions lack a critical mass in any specific industry and cannot easily rely on opportunities of meaningful recombinations for new path creation. Such regions are often dominated by small and medium-sized enterprises (SMEs) operating in traditional and resource-based industries, where innovation tends to be low and typically incremental. Furthermore, the presence of knowledge and support infrastructure, such as universities or R&D institutes, is rather deficient.

Therefore, both OIAs and peripheral regions are less likely to deploy their endogenous potential (if any) for new regional industrial path developments, encouraging 'mindful deviation' from existing paths (Garud and Karnøe, 2001). Consequently, scholars have stressed the importance of exogenous stimuli in non-core regions, though on different grounds. OIAs could struggle to overcome technological regimes that are regionally institutionalized (Crouch & Voelzkow, 2009), where incumbent organizations may resist change (Bork, Schoormans, Silvester, & Joore, 2015). As such, legitimation of new industrial trajectories cannot rely on a critical mass of actors that engage in 'institutional entrepreneurship' (Grillitsch & Sotarauta, 2018) and challenge dominant rules and norms through industry associations or collective agencies (Bergek, Jacobsson, & Sandén, 2008). Here, economic and industrial policies formulated at the level of state can shift the region's institutional environment (Gertler, 2010) and nudge new industrial trajectories with the help of public subsides combined with regional policy measures (Trippl and Otto, 2009). Furthermore, extra-regional actors and linkages can fuel the creation of a new path in exhausted industries (as the case of the automotive industry in Styria, see Trippl and Tödtling, 2008) or engage in transplantation as a means of triggering unrelated diversification in the region. Dawley et al. (2015) show that the interplay of multi-scale policy interventions, ranging from policies to attract firms and investments from elsewhere, to horizontal policies, sector-based vertical policies, and local development initiatives, has essentially shaped path development in the Scottish wind sector.

Conversely, peripheral regions typically have both weak formal and informal institutions (Rodríguez-Pose, 2013) and in-coming investments are often related to the exploitation of natural resources, or cheap labour and land (Trippl et al., 2018). In these areas, public policy is expected not only to engage with the enhancement of knowledge and support infrastructure (Mudambi & Santangelo, 2016), but also to supervise the settlement of extra-regional actors in the region, promoting their embedding and knowledge exchange with local actors (Dunning & Lundan, 2008). This means stimulating the process of 'strategic coupling' described by MacKinnon et al. (2019), by which 'regional actors seek to harness and match regional and extra-regional assets to multiple mechanisms of path creation' (ibidem, p. 121).

However, a policy intervention that is devoid of any effort to lessen established pattern of uneven development could exacerbate divergence among regions, thus jeopardizing higher national welfare gains. Extra-regional actors can counterbalance the inaction of public agencies, but their outcome may differ depending on the type of region under consideration. And, if not properly managed, the connection between FDI and regional development can have negative consequences in the long term, as regions can become 'locked-in to external networks (GPNs) controlled by powerful TNCs [transnational corporations] as is evident from the experiences of branch-plant regions which became over-reliant on relatively low-value production plants, lacking more advanced functions and high-status employment as a result' (MacKinnon, 2011, p. 236). A similar conclusion holds in the case of regions locked in out-dated technological regimes, whose dominance prevents the emergence or the diffusion of more ethical and sustainable innovations, a topic to which the paper now turns.

1.5 Unrelated Diversification and Sustainability Transitions

As any path dependent process, regional diversification can also lead to sub-optimal outcomes (David, 1985), meaning that 'systems can be locked into apparently inferior forms or trajectories even though more efficient alternatives were or are possible' (Martin & Sunley, 2006, p. 401). This is particular relevant for industries facing constant or diminishing returns (Arthur, 1988), where any means for new path trajectories 'reflects only a priori endowments, preferences and transformation possibilities' (Arthur, 1989, p. 127). Furthermore, in regions where a technological regime is also strongly aligned with localized learning, territorial institutions and vested interests, it's unlikely for a new industry to mark a radical departure from a region's own past (Boschma et al., 2017). Such conditions apply to industries relying on exhaustible resources, such as energy, water, housing and food, notably those societal systems of provision that are expected to comply with higher standards of sustainability (Mathews & Reinert, 2014). Here, the scope for diversification into new, sustainable configurations is constrained in the region by the strength of the existing socio-technical regime (Truffer & Coenen, 2012). Although Van Den Berge & Wetering (2014) showed that relatedness is a major driver for the emergence of new clean technologies within EU regions, a systematic attempt to extend this analysis to industrial diversification is still missing.

Conversely, Transition Studies have devoted great attention to the initiation of new pathways through disruptive processes of technological change and innovation, focusing on the emergence of new technologies that struggle against incumbent actors and regimes (Raven, Kern, Verhees, & Smith, 2016). This is mostly conceptualized through the notion of niches (Geels, 2004), which are defined as 'incubation spaces' for radically new technologies and/or practices. Such niches protect radical novelties against market selection and institutional pressure from a dominant sociotechnical regime, as far as they gather sufficient momentum to become institutionalized and induce transitions (Boschma et al., 2017). The relation between niches and regimes can be understood in terms of legitimation and anchoring, two overlapping processes by which a novelty overcomes its 'liability of newness' (Geels & Verhees, 2011) and becomes aligned with a regime (Binz et al., 2016).

Although this framework has been mostly divorced from the analysis of the spatial structure and preconditions, a large majority of case studies has raised awareness in this scholarly field about the importance of place-dependence for transition processes (Hansen & Coenen, 2015). Thus, the construction of niches, though challenging a socio-technical regime that is globally dominant, takes place thanks to actors embedded in a specific regional system, with its own territorial institutional and vested interests. By these means, the concept of niche formation shares a common ground with the concept of unrelated diversification, as they both engage with the 'nature, loci and radicalness of novelty' (Boschma et al., 2017, p. 37), but they should not be confused. The former applies to innovations that are new to the world, while the latter to those new to the region. In a first attempt to outline a cross-field framework, Binz et al. (2016) showed, for the water-tech industry, that a niche formation is highly dependent on the institutional entrepreneurship engaged by public and private actors to adapt the new industry to pre-existing institutional structures and vice-versa (Fuenfschilling & Truffer, 2016). Finally, Boschma et al. (2017) derived a typology of four different regional diversification processes, distinguished along their sectorial dimension (regime or niche) and their regional dimension (related or unrelated). On one hand, replication and transplantation are conceived as processes driving regions to related or unrelated diversification within a dominant global regime. On the other hand, exaptation and saltation refer to diversification logics where new-to-the-world applications are discovered by recombining existing regional knowledge bases in related or unrelated way, thus ascribable to the concept of the niche.

Nevertheless, this process of 'mindful deviation' from dominant regime could be harder for those industries and regions experiencing sustainable transitions. This is plausible on at least three grounds. First, the vast majority of cleantech sectors cannot overcome the sunk-cost advantage of incumbent technologies and, therefore, their products internalize higher production costs. As such, they will likely continue to be marginal technologies that cannot accelerate the transition needed to undertake those grand societal challenges, such as climate change, ageing societies and food security (Coenen et al., 2015). This is notably the case of the renewable energy industry, where the so-called 'grid parity' with fossil fuels is still far to be achieved (Mazzucato, 2013). Second, regional incumbent actors lobby for preventing regulatory changes and diverting allocations of funds, as they reflect a bargaining power accumulated over longer periods of time. As such, necessary changes are implemented slowly and incrementally, even in the face of external threats such as climate change (Essletzbichler, 2012). Finally, sustainable transitions are likely to occur in those regions whose economic and institutional environment is more related and/or less hostile to the radical novelties needed to provide those transitions. Conversely, lagging regions will struggle to overcome their old technological configurations by means of unrelated diversification, as they lack both innovative and institutional entrepreneurship (Grillitsch & Sotarauta, 2018). Under these assumptions, opportunities for path creation are dependent on the introduction of favourable policy regimes and financial instruments by government and supra-national institutions (Essletzbichler, 2012). This is bound up with the broader role of the State in influencing path creation with policies directed at both the demand and supply side. Mazzucato (2013) showed that this was the case for the United States, where the Federal Government has aggressively deployed public finance with the aim of promoting green industry. Dawley et al. (2015) gathered similar evidences for the offshore wind sector in UK, where path creation was crucially supported by national policy interventions.

1.6 Final remarks

The paper has discussed recent contributions on regional diversification in light of the debate undergoing in different strands of literature since the seminal contribution of Martin and Sunley (2006). To start with, it remarks a key finding in EEG, that is the accumulating evidence on related diversification in regions (Kogler, 2015). Notwithstanding different methodological approaches, relatedness proves to be a dominant mechanism of regional de-locking and path creation. It is argued here that further research should engage with a less nuanced conceptualization of capabilities and human agency. In the second section, it explores the conditions and sources of unrelated diversification, a more risky and uncertain process for regions that is mediated by their institutional environment and triggered by extra-regional actors. It is claimed that the scope for diversification considerably varies between regions and is narrower for lagging and peripheral ones. Accordingly, unrelated diversification is depicted as deeply embroiled with the broader question of uneven regional development, which calls for an active role of policymakers. A similar theoretical proposition is then advanced with regard to sustainability transitions, which are potentially undermined by technological and institutional rigidity in the region.

This work mainly engages with Evolutionary Economic Geography, but it draws insights from neighbouring literatures on sociological approaches to path creation, transition studies and geographical political economy. The aim is contributing to the integration of mixed methods and theoretical approaches in the study of regional diversification, calling for the implementation of both quantitative and qualitative studies. Most notably, it promotes a broader perspective on path creation, which cannot be seen as a purely endogenous and micro-economic process, because it is also shaped by extra-regional, political, institutional and macro-economic factors.

In light of above, the article intends to provide specific directions for further research. First, it takes side with recent contributions that advocate a more systematic scrutiny of the role of the public agencies driving the process of regional diversification (Boschma, 2017). Public agencies can play a major role in developing new industries, by fuelling the system with the 'patient capital' needed for the emergence and diffusion of radical novelties (Mazzucato, 2013). This line of inquire has been largely neglected so far and very little is known about the role of public policies in stimulating diversification within regions. Specifically, systematic evidence is missing on how public funds for R&D, either directed towards private or public actors, can actually trigger the development of new technologies and, hence, of new industries. Second, future research should more explicitly target those enabling and disabling conditions that alter the generation of novelty in OIAs and peripheral regions, as compared to core regions. This also entails a proper assessment of how similar processes and mechanisms of path creation operate differently across regions according to their position within wider political and economic relations (Morgan, 2013). Indeed, new paths in peripheral regions could actually exacerbate what has been termed the 'dark side of path creation' (Phelps, Atienza, & Arias, 2018; Winter, 2018), with the generation of new forms of inequality, uneven resource allocation and extra-regional path interdependence (MacKinnon et al. 2019). Finally, the relationship between sustainable transitions and unrelated diversification represents another understudied dimension. In particular, there is a need to determine the role of different economic actors and institutional players, including policy-makers, in legitimating and empowering emerging sustainable paths and to assess which type of (more or less related) diversification they help to unlock.

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2. WHAT DRIVES TECHNOLOGICAL CHANGE IN REGIONS? RELATEDNESS AND POLICY SUPPORT IN THE US FROM 1981 TO 2010

by ANDREA SIMONE

ABSTRACT

Innovation policies are unanimously acknowledged as a major spurrer of the economic development of regions, but are seldom considered in the literature concerning regional diversification. Conversely, robust evidence has been gathered about the impact of relatedness on the ability of regions to explore new technological domains. The work employs patent data to assess the extent to which related and unrelated diversification processes in the United States, between 1981 and 2010, are influenced by the existing regional knowledge base and the magnitude of R&D public funds, providing evidence for both drivers by means of econometric estimations.

KEYWORDS: diversification, technological relatedness, public policy

2.1 INTRODUCTION

The emergence of new industrial paths and the determinants of regional diversification lie at the heart of a lively debate in economic geography, especially in light of its evolutionary turn (Martin & Sunley, 2006). From an evolutionary perspective, there is strong consensus that regions are most likely to diversify into industries that are technologically related to their already existing local production, by means of combinatorial knowledge dynamics and branching processes. Several studies have confirmed the predominance of related diversification despite differences in the measures of relatedness, scales of analysis and time periods covered (see, e.g., Hidalgo, Klinger, Barabasi, & Hausmann, 2007; Neffke, Henning, & Boschma 2011; Neffke & Henning, 2013; Tanner, 2014; Essletzbichler, 2015; Rigby, 2015; Boschma, 2017; He, Yan, & Rigby, 2018).

Nevertheless, this conceptual approach has also drawn several lines of criticism (Hassink, Klaerding, and Marques, 2014; Henning, Stam, and Wenting 2013). On one hand, evidence has been gathered about the occurrence of unrelated diversifications, suggesting that care should be taken in ascribing the logic of regional diversification to the principle of technological relatedness alone. (Andersson, Bjerke, & Karlsson, 2013; Boschma & Capone, 2015; Petralia, Balland, & Morrison, 2017; Xiao, Boschma, & Andersson, 2018). On the other hand, but interwoven with the first, the focus on technological relatedness tends to downplay the pivotal role played by extra-regional firms, non-industrial actors and public policies in creating or reinvigorating industrial development paths in advanced and industrialized regions (Binz, Truffer, & Coenen, 2015). Most notably, public policies can either reinforce the role of industry relatedness, by assisting regional branching into related sectors (Boschma, 2013; Asheim, Boschma, & Cooke, 2011), or act disruptively by harnessing existing regional assets and local knowledge into new unrelated activities (Dawley, MacKinnon, Cumbers, & Pike, 2015; Trippl, Grillitsch, & Isaksen, 2018). In this framework, innovation policies, like the provision of R&D subsidies, can make the development of some industries and technologies in some places more feasible (Uhlbach, Balland, & Scherngell, 2017; Broekel & Mewes, 2017). The way industrial branching processes interact with public incentives in shaping a region's industrial structure represents a thriving field of investigation in regional studies and policymaking that still deserves further contributions.

Following these studies, the paper aims at assessing to what extent diversification processes in the United States, between 1981 and 2010, have been influenced by prior technological expertise in related fields and/or by R&D policies undertaken by federal agencies at the state level. A logistic regression model for longitudinal data with fixed effects has been estimated, mainly employing two sets of data: patent data from OECD REGPAT, to measure technological relatedness between 4-digit major patent classes within the International Patent Classification (IPC), and data on US Federal Obligations for Research & Development, collected from the annual survey of the National Science Foundation (NSF).

The contribution of this article is twofold. First, in line with Neffke, Hartog, Boschma, & Henning (2018), a measure of *regional capability match* has been developed to determine the degree of relatedness between an industry and a region overall industry mix, but adopting a novel approach that makes use of patent data instead of labour flows. Hence, its impact on the acquisition of a Revealed Technological Advantage (RTA) in a major patent class has been quantified for 643 4-digit IPC classes and for the 50 United States (plus District of Columbia) over a period of more than 30 years, in the footsteps of the pioneering work proposed by Rigby (2015).

Secondly, this work empirically validates the hypothesis that supply-side innovation policies (Mazzucato, 2013), by means of R&D subsidies, have a measurable impact on the ability of regions to diversify. Moreover, it provides evidence on how this impact varies with respect to related and unrelated diversification processes and/or typology of subsidy recipient. Therefore, the quantitative framework developed here informs current debates in Evolutionary Economic Geography (EEG) by deliberately incorporating the State in the analysis of industrial transitions, thus helping to build "a systematic view on the State that is well grounded in evolutionary thinking" (Boschma & Martin, 2010, p. 23).

The outline of the paper is as follows. The next two sections describe more extensively why regional innovation processes tend to be path dependent and how the existing structure of a region may affect the likelihood of developing new technologies. Afterwards, the article takes into account other sources of regional diversification, with particular reference to the role of public agency and the impact of R&D policies in fuelling new path creation. Accordingly, three research hypotheses are proposed following the theoretical framework outlined. The fourth and fifth sections display, respectively, the methodological framework adopted for measuring technological relatedness and the econometric model. Finally, the sixth section presents the empirical results and the main findings. The seventh section concludes.

2.2 RELATEDNESS AS DRIVER OF DIVERSIFICATION

Regions are subject to a never-ending process of creative destruction that Schumpeter (1939) considered the driving force behind economic development. In the long term, regions rely on their ability to create and attract new industries to offset other parts of their economies' decline and destruction (Grahber, 1993; Storper, 1995; Cooke & Morgan, 1998). Indeed, the ever-increasing pace of technology life-cycles makes it harder for most regional economies to achieve long-term growth by relying on their traditional specializations. Such risks are even greater for developed, industrialized economies because the division of design and manufacturing activities within the global economy implies that places of imagination are seldom the same as places of production and therefore, for the most part, the secret to a long-term competitive advantage lies in the continuing technological development or knowledge production (Maskell & Malmberg, 1999; Gertler, 2003; Scott, 2006).

Since the late 2000s, EEG's scholars have seized on the notion of path dependence as a key epistemological paradigm to explain how regional economies evolve through time and, foremost, why they either become locked into development paths that lose dynamism or seem able to avoid this danger by exploring new industrial trajectories (Martin & Sunley, 2006). Path dependence entails that "industrial history is literally embodied in the present" (Walker, 2001, p. 126), though it does not imply historical determinism or "past dependence" (Håkansson and Lundgren, 1997): the past inheritance only sets the initial conditions for the further evolution of economic structures (Lawson, 1997). Thus, a common view in EEG is that new technologies generally do not emerge in virgin markets but exploit (at least in part) already developed routines at local level. With respect to micro-perspective, Klepper (2007) showed that new regional industries emerge by means of spinoffs or breakaways from entrepreneurs with experience in related fields, from which they draw and combine local capabilities. Connecting the idea of path dependence and branching processes in related industries, several studies have put forward the concept of *relatedness* to explain industrial diversification of countries (Hidalgo et al., 2007; Hausmann & Klinger, 2007), regions (van den Berge & Weterings, 2014; Tanner, 2014), or cities (Neffke et al, 2011; Boschma, Balland, & Kogler, 2014; Essletzbichler, 2015). These studies showed that relatedness is a fundamental driving force of diversification at national and sub-national scale. However, the related diversification process is stronger at a regional rather than at a country level (Boschma, Minondo, & Navarro, 2013), as innovation is characterized by strong distance decay effects of knowledge spillovers that result in geographically localized search and adaptation processes (Essletzbichler, 2012).

Although widely used in the literature, there is not unanimous consensus about the definition and measurement of relatedness. A common strategy assumes relatedness among different industries when they co-occur in the same portfolio of products, at the level of export or production (Hidalgo et al., 2007; Bryce & Winter, 2009; Neffke et al., 2011; Boschma et al., 2013). Other approaches make use of resource-based indicators (Fan and Lang, 2000; Breschi, Lissoni, &

Malerba, 2003) to detect similarities among the resources employed in different industries, such as commodity flows, human capital and technological resources. With respect to the latter, a first attempt to provide a technological relatedness measure can be traced back to Breschi et al. (2003) and is based on the co-occurrence of technology classes in patent documents. This strategy has been adopted by Rigby (2015) to verify the impact of relatedness on technological diversification in US metropolitan regions (between 1975 and 2005), and, subsequently, by several other studies (see, e.g., Boschma et al., 2015; van den Berge & Weterings, 2014). Analogously, measures of occupational or skill relatedness have also been employed (Muneepeerakul, Lobo, Shutters, Gomez-Lievano, & Qubbaj, 2013; Neffke et al., 2018), delivering similar conclusions.

In sum, related diversification is found to be a dominant pattern in industrial evolution of places, despite the adoption of different methodological approaches and scales of analysis. Hence, one of the expected outcomes of this work is to deliver consistent evidence on the role of technological relatedness on the diversification pattern of the United States for the time frame considered, following the RTA approach of Rigby (2015) for the definition of diversification. The following hypothesis can thus be put forward:

Hp1: *The region's capacity of constructing new revealed technological advantages (RTAs) is positively correlated with technological relatedness.*

Despite the large evidence showing the importance of relatedness as an enabler of diversification, some regions appear to be able to diversify in new industrial sectors that have no technological predecessors or antecedents locally. Specifically, negative effects of relatedness on the entry probability of a new activity in a region have been occasionally found (Boschma & Capone, 2015; Zhu, He, & Zhou, 2017), meaning that, wherever this occurs, "regions make jumps in their industrial evolution, and unrelated diversification prevails" (Boschma, 2017, p. 355). So far, these studies have shown that this is a rather exceptional event, since it entails a more uncertain and risky process (Saviotti & Frenken, 2008). Like all actors, firms are characterized by bounded rationality, and high risks as well as switching costs preclude them from building completely new innovations from scratch (Breschi et al., 2003; Boschma et al., 2013; Makri, Hitt, & Lane, 2010); thus, they concentrate on technology domains that present similarity in problem solving and knowledge bases (Nelson & Winter, 1982; Dosi, 1997). However, recent studies have also proved that unrelated diversifications can actually lead to long-lasting competitive advantages, since these processes are likely to be associated to higher rates of breakthrough innovation that it might be difficult for other regions to replicate (Castaldi, Frenken, & Los, 2015). As a result, later research in EEG has been investigating the enabling or constraining factors that make regions more or less apt to diversify into unrelated activities (see, e.g., Andersson et al., 2013; Boschma & Capone, 2015; Petralia et al., 2017; Xiao et al., 2018), but systematic evidence is still lacking (Boschma, 2017).

What is evident from recent studies is that relatedness is a powerful but insufficient predictor for the future innovative trajectories of firms or regions. These conclusions come close to those drawn by several contributions (see, e.g., Coe, 2011; MacKinnon, 2011; Dawley et al., 2015) that criticise the EEG approach for being too focused on the micro-economic realm (Morgan, 2013) and tending to "conceive of regional diversification as a largely endogenous of firms" (MacKinnon, Dawley, Pike, & Cumbers, 2019, p. 116). In fact, by emphasizing the role of local conditions and processes, EEG scholars have not only underplayed the role of extra-regional actors, linkages and networks (Coe, 2011; MacKinnon, 2011), but also the role of national State strategies and public policies (Morgan, 2013, MacKinnon, Dawley, Pike, & Cumbers, 2019). These factors can either facilitate dynamics of regional branching in related fields or induce diversification in new technological domains that are unrelated to the existing regional knowledge base. As a result, recent calls in the literature (Pike, MacKinnon, Cumbers, Dawley, & McMaster, 2016; Trippl et al., 2018) advocate a multi-actor perspective that takes into account other sources of regional diversification. Several contributions highlighted the role played by extra-regional knowledge linkages and actors in fostering both related (Boschma & Iammarino, 2009; Andersson et al., 2013; Boschma, Balland, & Kogler, 2015; Boschma, Martin, & Minondo, 2017) and unrelated diversification (Dawley, 2014; Mudambi & Santangelo, 2016; Isaksen & Trippl, 2014). However, little evidence has been gathered so far on how public agency can foster the creation of new industrial paths or the adaptation of existing ones. Therefore, there is a need to increase our understanding of how public policies, and specifically supply-side innovation policies (Mazzucato, 2013), can facilitate more related or more unrelated diversification in regions, a topic to which now the paper turns.

2.3 PUBLIC R&D FUNDING AND ITS ROLE FOR REGIONAL DIVERSIFICATION

As repeatedly stressed in a growing literature on the subject (Garud, Kumaraswamy, & Karnøe, 2010, Binz, Truffer, Li, & Shi, 2012, Isaksen & Trippl, 2014), even in some of the most successful cases of path creation, the mechanisms involved "are not purely market branching processes but are significantly intermediated by regional and national agencies" (Cooke, 2010, p. 10). Throughout history, the development of several breakthrough inventions can be linked to government incentives, especially in strategic fields like ICT, biotechnology, and nanotechnology (Motoyama, Appelbaum, & Parker, 2011; Blumenthal, 1998; Arnold, 2012). Even behind the most prominent technological revolutions in the past – from the Internet to the green tech –traditionally ascribed to market-driven processes, there has been a massive push by policy interventions. In 'The State behind the iPhone" (Mazzucato, 2013) the author mentions a 2006 policy document (OSTP, 2006) showing how the various component technologies featured in the first-generation of Apple products "were linked to their origins as part of the basic and applied research funded by US tax dollars" (Mazzucato, 2013, p. 116). In a recent work, Mazzucato (2016) further stresses the link between innovation and industrial policy, arguing that public policy cannot simply fix market and system failures (Aghion, David, & Foray, 2009, Frenken, 2017), but should also directly create technological opportunities and markets.

Nevertheless, the traditional approach of R&D policy wasn’t designed to support technological diversification, but rather to foster inventive activities in a selected number of promising technologies, according to the prevailing linear view on innovation (Frenken, 2017). The main shortcoming of this approach is that it does not recognize the specific economic and innovation-related situations of regions, which in many cases led to a loose connection between funded innovation initiatives and regional capabilities (Tödtling & Trippl, 2005; Foray, David, & Hall, 2011). Political support has been effective in promoting specific areas in some cases, but since they lack any regional embeddedness they finally tend to be 'cathedrals in the desert' (Boschma and Gianelle, 2014) with limited impact on regional development.

As a result, scholars have increasingly questioned the validity of such 'one-size-fits-all' approaches. On the contrary, more consideration should be given to the individual situation of regions in R&D policy (Tödtling and Trippl, 2005). The Construction of Regional Advantage (CRA) approach is a prominent example of such new policy design (Oughto, Landabaso, & Morgan, 2002; Asheim et al., 2011; Boschma, 2011). The CRA approach explicitly acknowledges technological relatedness as the main driver of regional diversification and calls for the implementation of policies that take into account regions’ core activities (Foray et al., 2011; McCann and Ortega-Argilés, 2013). Analogously, the EU’s Smart Specialization Policies (S3) aim at linking technological growth incentives to the specific knowledge base of regions, in order to foster related technological diversification. The existence of R&D activities in related fields causes synergies between local R&D domains and increases the exploitation and experimentation of technological opportunities (Foray et al., 2011). This approach has been empirically validated by few recent contributions. The work of Coenen, Moodysson, & Martin (2015) explores opportunities, challenges and limits of regional innovation policy implemented to renew mature industries. For the case of Northern Sweden's forest industry, the authors demonstrate that regional innovation policy can accompany the regional diversification process by promoting the adoption and development of related technologies. Uhlbach, Balland & Scherngell (2017) gathered robust evidence about the positive relation between R&D subsidies and new technological specializations of European regions from 1999 to 2010. Conversely, Broekel & Mewes (2017) analysed the relation between R&D policy and regional technological diversification in German labour market regions from 1996 to 2010, but found no evidence for proactive R&D policies. However, the relation between public policies and regional diversification is still blurred and deserves further contributions (Boschma and Gianelle, 2014). Accordingly, and in line with the main objectives of this paper, the following hypothesis will be tested with respect to the United States in the time frame 1981-2010:

Hp2: *Public R&D funds are positively correlated with the construction of new RTAs*

Nevertheless, when the distribution of subsidization follows the principle of relatedness, two fundamental weaknesses can be identified. First of all, as put forward by the new industrial policy literature (Rodrik, 2004; Aghion, Boulanger, & Cohen, 2011; Mazzucato, 2016), public policy should play a key role in launching processes of diversification that would be otherwise not easily achievable (Rodrik, 2004; Morgan, 2013). Moreover, regions over-relying on branching process could actually be trapped in path exhaustion (Isaksen, 2014) and their goal to escape from 'lock-in' could narrow. Hence, a related diversification strategy should also go hand in hand with an unrelated-diversification strategy. In other contexts, one also speaks of the exploration versus exploitation and the need for 'ambidexterity' (Frenken, 2017, p. 41). So far, there is no systematic analysis of the impact of innovation policies with respect to related and unrelated diversification processes. As regards the present work, the latter are expected to be significantly more reliant on the magnitude of policy support. In fact, as pointed out by Mazzucato (2013), the long-term commitment and 'patient' capital provided by the US government allow for risky endeavours in large research programs, that are more likely to deliver unrelated diversification in regions. So, the following hypothesis will be tested:

Hp3: *Correlation with public R&D funds is higher for unrelated diversification processes than for related ones*

A second weakness of the relatedness-based approach is that large firms tend to benefit more from public R&D incentives than small firms, because they perform more R&D on average and have formal R&D departments to which tax benefits apply. Also, funds are often awarded in form of competitive bidding (Tödtling and Trippl, 2005), thus only those firms that are already successful in specific technologies are likely to receive support. Hence, R&D subsidies to industrial firms are most likely to reinforce existing specializations dominated by large firms (Frenken, 2017), with detrimental effect on further regional diversification. Consistently with these premises, R&D funds to industrial firms are expected to be loosely correlated with the entry probability of a new specialization in the United States. Conversely, subsidies allocated to non-industrial actors (such as universities, non-profit research institutes or government-owned R&D facilities) are expected to have a positive and significant effect on the ability of states to diversify. Thus, the validity of Hp2 and Hp3 will be subject to further empirical application, as follows:

Hp2a: *Public R&D funds allocated to industrial firms are negatively correlated with the construction of new RTAs*

Hp2b: *Public R&D funds allocated to non-industrial actors are significantly and positively correlated with the construction of new RTAs*

Hp3a: *Negative correlation with public R&D funds allocated to industrial firms is expected to be higher for unrelated diversification processes as compared to related ones.*

Hp3b: *Positive correlation with public R&D funds allocated to non-industrial is expected to be higher for unrelated diversification processes as compared to related ones.*

Summing up, the main claim of this work is that the evolution of the productive structures of United States, between 1981 and 2010, is affected, *inter alia*, by the level of technological relatedness and the national R&D policies at state level. I also claim that this effect varies with respect to related or unrelated diversification, and the typology of beneficiaries of policy interventions. Before moving to the methodological approach and the empirical test of the proposed hypotheses, it should be noted that the present study focuses on one of the available instruments of R&D policy, namely the R&D subsidies. Although they are not specifically designed to support technological diversification activities, they have a significant potential of being effective in this manner. Moreover, the scale of analysis adopted is the state level, as the distribution of R&D funds among sub-regional entities (like counties, MSAs or cities) is not available.

2.4 MEASURING TECHNOLOGICAL RELATEDNESS USING PATENT DATA

For the purpose of this work, patent data from the OECD REGPAT databases (OECD, July 2019) have been employed, including all patents applications filed to the United States Patent and Trademark Office (USPTO). Patent statistics have been widely used in quantitative studies given their availability and the wealth of information that they encompass (Pavitt, 1985; Frenken, van Oort, Verburg, 2007). At the same time, the disadvantages of patent statistics as overall measure of economic and inventive activity are well known (Griliches, 1990). In general, four main categories of information are available in REGPAT: the content of the innovation activity carried out (title, words, abstracts and IPC classes); inventors and organizations involved; geographical location (address of the inventor and the applicant); year of application and grant. Patent applications are linked to the region on the basis of inventors' address[1]. For single inventor patents this is straightforward; in case of multiple inventors, a proportional share is assigned to each region, following the fractional counting method developed by Narin & Breizman (1995) and endorsed by a number of OECD documents (see, e.g., Maraut, Dernis, Webb, Spiezia, & Guellec, 2008). Also, the year of application has been preferred to the patent grant year, due to the time-lag from the date of invention and filing to the grant date (Kogler, Rigby, & Tucker, 2013). The total count of unique patent applications filed by the USPTO in the period of analysis (1981-2010) was 747.178. The research below takes into account all the 643 IPC classes (4-digit) of utility patents in use by the USPTO[2] by the end of 2010.

As outlined in the second section, technological relatedness between industries can be measured in several ways (Neffke & Henning, 2013). The methodological strategy adopted here follows

[1] The association of patents to specific regions was not possible for 17.692 patent applications (0,71% of the total), which have consequently been excluded from the analysis.

[2] It is important to note that over time these categories of technology do not remain constant. The USPTO redefines classes through its bi-monthly ' classification orders, ' adding new classes and, although unusual, eliminating obsolete classes.
Luckily, the USPTO also reclassifies patents, offering a consistent set of technologies categories in which patents are placed for specific time periods.

Neffke et al. (2018), but introduces a novel approach that makes use of patent data instead of labour flows. Accordingly, this strategy involves three steps: (1) determination of the *inter-industry relatedness*. Building on the previous indicators; then (2) a *regional capability match* index is calculated, which measures how related an industry is to the region's overall industry mix; finally, regional coherence is quantified as (3) the average capability match of all industries in a region. This procedure is laid out in the following paragraphs.

Inter-industry relatedness

Following Breschi et al. (2003), inter-industry relatedness is based on the co-occurrence of classification codes assigned to individual patent documents (Engelsman & van Raan, 1991). Patent applications are categorized by at least one International Patent Classification (IPC) classification code (main or primary), but more classification codes (secondary or supplementary) are typically assigned to the documents by the issuing patent offices' examiners. Here, the assumption is that the frequency by which two classification codes are jointly assigned to the same patent document can be interpreted as a sign of the strength of the knowledge relationship between the technological fields. Contrary to Verspagen (1997), there is no assumption about the meaning of the main classification codes as opposed to the secondary ones, so all the classification codes assigned to a patent document are weighted in equal measure.

Similarly to van den Berge & Weterings (2014), the relatedness between each IPC class *i* with every other IPC class *j* at the 4-digit level is computed by taking the normalized co-occurrence within all patents. A probabilistic similarity measure is adopted, i.e. the association strength, as proposed by Eck & Waltman (2009). The probabilistic approach delivered a measure of the co-occurrence of technology *i* and *j* is equal to:

$$TR_{ij} = \frac{P_{ij}}{e_{ij}}$$

where TR_{ij} stands for the technological relatedness between technology i and j, P_{ij} for the observed co-occurrence between i and j, and e_{ij} for the expected co-occurrence. This measure has the following probabilistic interpretation: $P_{ij}/e_{ij} > 1$, when i and j co-occur more frequently than would be expected by chance, and $P_{ij}/e_{ij} < 1$ when i and j co-occur less frequently than would be expected by chance. The expected co-occurrences is computed as:

$$e_{ij} = \left(\frac{P_{i.}}{P_{..}} \frac{P_{.j}}{P_{..}}\right) P_{..}$$

where the dots represent sums over the omitted category, such that $P_{i.} = \sum_j P_{ij}$, $P_{.j} = \sum_i P_{ij}$ and $P_{..} = \sum_{i,j} P_{ij}$. Therefore, $P_{i.}$ and $P_{.j}$ represent the total occurrences of technology i and j, respectively, in the REGPAT database during the period in consideration, and $P_{..}$ stands for the total number of patents in the same period. In one formula:

$$TR_{ij} = \frac{P_{ij}}{(P_{i.}P_{.j})/P_{..}}$$

This resulted in a symmetric square matrix ($IPC \times IPC$) of order $n = 643$.

Industry-Region Capability Match

In the second step, *industry-industry* pairs are employed to compute *industry-region* pairs, which deliver the degree of relatedness of an industry to the overall industry mix of a region. There are several ways to do this, as shown in Hidalgo et al. (2007) or Teece, Rumelt, Dosi, & Winter. (1994), where the calculation implies the average association of a product with all over-represented products in the export basket or the employment-weighted average association of an activity with all other activities of a firm. Here, a different method is used, following the contribution on regional diversification as proposed by Neffke et al., 2011 (see also Delgado, Porter, & Stern, 2014; Neffke et al., 2018). Regional diversification is measured by looking at how much of the overall patent activity of a region is related to an industry. In particular, let P_{irt}^{rel} be the total amount of patents in industries related to industry *i* in region *r* in year *t*:

$$P_{irt}^{rel} = \sum_j I\left(TR_{ij} > 1\right)P_{jrt}$$

where P_{jrt} represents the patents of industry *j* in region *r* in year *t* and $I(TR_{ij} > 1)$ an indicator function that is equal to one if its argument is true and to zero otherwise. In this way, patents unrelated to industry i (i.e. $TR_{ij} < 1$) are not considered in the count, while all the others (i.e. $TR_{ij} > 1$) are weighted with respect to the level of technological relatedness with industry i. The match of industry i to region r in year t is defined as the degree to which the region is overspecialized in industries related to industry i. That is, it is based on the location quotient of related patents (LQ_{irt}^{rel}):

$$LQ_{irt}^{rel} = \frac{P_{irt}^{rel}/P_{.rt}}{P_{i.t}^{rel}/P_{..t}}$$

where, P_{irt}^{rel} the total patents in related industries in year t, $P_{.rt}$ is regions r's total count of patents in year t, $P_{i.t}^{rel}$ the total patents in related industries for all regions in year t, and $P_{..t}$ the total national count of patents in year t.

As a result, LQ_{irt}^{rel} has a highly asymmetric distribution: the over-representation of related industries can range from 1 to infinity, whereas the under-representation of related industries can range only from 0 to 1. I measure the industry's match to a specific region using the following monotone transformation, in order to prevent this asymmetry from skewing further derived quantities:

$$CM_{irt} = \frac{LQ_{irt}^{rel} - 1}{LQ_{irt}^{rel} + 1}$$

This index maps over- and underrepresentation of related industries symmetrically around 0, such that CM_{irt} ranges from -1 (unrelated patent activity) to +1 (fully related patent activity is concentrated in region *r*).

Regional Coherence

While the capability match is a characteristic of a local industry, that is, an *industry-region* pair, coherence represents how well all the industries of a region work together, that is, coherence is a *regional* feature. Therefore, I define coherence as the average patent-weighted capability match between the industries of a region:

$$C_{rt} = \sum_{i} \frac{P_{irt}}{P_{.rt}} CM_{irt}$$

Coherence informs us on how related the industries of a region are to one another.

The econometric analysis performed in the following employs the regional capability match as the main regressor, while coherence has been used as a synthetic indicator to map the evolution of regions' overall industry mix over time.

2.5 THE ECONOMETRIC MODEL

Dependent variable

Before going into the details of variables' specifications, it is now fundamental to explicitly define what is meant here by the term 'diversification'. The meaning of diversification is, at least, twofold (Neffke et al., 2018). It could be considered as a static phenomenon, in terms of degree of internal variety, and consequently measurable by means of entropy or Herfindal indexes. Alternatively, it could be interpreted as a dynamic phenomenon, i.e. the structural change involving the portfolio of local economic activities. The analysis carried out in this paper endorses the dynamic counterpart. Moreover, diversification can occur at the level of economic activities, or at the level of local capabilities. The latter is consistent with the measurement strategy entailed by resource-based indicators (Neffke & Henning, 2013), as the one developed here, and tracks the evolution in the knowledge base of a region that underlies industrial change. As a result, the concept of diversification adopted here refers to the *structural change* of local capabilities, which is intended here as the acquisition of new technological specializations. A viable approach to detect a technological specialization in a regional economy (Rigby, 2015) is to calculate a Revealed Technological Advantage (RTA), which is defined as "the share of an economy's patents in a particular technology field relative to the share of total patents in that economy" (OECD, 2013, p. 222). The RTA in the technology class *i* of a region *r* in the year *t* is consequently calculated as follows:

$$RTA_{irt} = \frac{P_{irt}/\sum_i P_{irt}}{\sum_r P_{irt}/\sum_r \sum_i P_{irt}}$$

RTA_{irt} is a continuous positive variable, and it is equal to zero when the economy has no patents in a given field; is below or equal to 1 when the economy's share in the sector is inferior to or equals its share in all fields (no specialisation); and above 1 when a positive specialisation is observed. Therefore, as usually done (see, e.g., Boschma et al., 2013; 2014; Rigby, 2015; Boschma & Capone, 2015), the dichotomous variable $ENTRY_{irt}$ is created, which takes the value of 1 for the first period in which a region has a share of patents in technology *i* that is higher than the US average, i.e. when its relative $RTA_{irt} > 1$. Conversely, it has a score of 0 for all the other years. By employing it as dependent variable, $ENTRY_{irt}$ can be consequently interpreted as the probability of a region to acquire (i.e. to diversify into) a new technological specialization (van den Berge & Weterings, 2014).

Independent variables

The hypotheses formulated in the previous sections require two distinct sets of regressors to be empirically validated. Specifically, to test *Hp1*, the regional capability match CM_{irt}, as developed earlier, has been employed. By these means, it is tested whether a new specialization in the technology class *i* is more likely to be acquired in regions that have higher values of technological relatedness to that class.

To test *Hp2*, the choice has been to employ the data on the US Federal R&D funds provided by the NSF in its annual Survey of Federal Funds for Research and Development (Federal Funds Survey), which is the primary source of information about federal funding for R&D in the United States[3]. Annual data are available for fiscal years (1951-2018), but they have been collected for the period 1981-2010, accordingly with the time frame of the analysis. The geographical distribution of R&D funds is available at the state level. Yearly total counts of R&D funds have been log-transformed, which is a common procedure to make highly skewed distributions less skewed (Verbeek, 2008). Finally, per capita indexes have been calculated dividing the yearly counts by the total state employment. For this purpose, the Employment data provided by the United States Census Bureau in its Economic Annual Surveys[4] are used.

Consequently, the following variable has been developed:

$$l\_R\&D_{rt} = log\left(\frac{R\&D_{rt}}{E_{rt}}\right)$$

where $l\_R\&D_{rt}$ is the per capita R&D funds granted in year *t* to region *r*, $R\&D_{rt}$ its total amount, and E_{rt} the total state employment. By using the variable $l\_R\&D_{rt}$ as a second regressor of the dependent variable $ENTRY_{irt}$, concurrently with the other regressor CM_{irt}, the aim is to quantify the effect of R&D funding on the ability of a region *r* to diversify into a new technology class i, *given* the technological relatedness of the region to that class.

As *Hp3* requires testing the impact of R&D funding on related and unrelated diversification processes separately, a viable procedure to do that is running two separate regressions for positive and negative values of CM_{irt}. Success or failure of a region to acquire a new RTA in technology class *i* has consequently been regressed on the amount of per capita R&D funds, given the degree of each region's technological relatedness (positive values of CM_{irt}) or unrelatedness (negative values of CM_{irt}) to the technology class i.

Finally, as *Hp2a, Hp2b, Hp3a* and *Hp3b* refer to specific subgroups of R&D funds, four types of funds' recipient are distinguished: (1) *intramural*[5] and *Federally Funded Research and Development Centers* (*FFRDCs*); (2) *industrial firms*; (3) *universities* and *colleges*; and, (4) *other non-profit institutions*. The NSF's survey provides the annual distribution of R&D funds among the four categories, so the computation is straightforward. In line with the procedure outlined before, the following variables have been composed:

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[3] The following Federal Agencies are surveyed: Departments of Agriculture; Department of Commerce; Department of Defence; Department of Energy; Department of Health & Human Services; Department of Interior; Department of Transportation; Environmental Protection Agency; National Aeronautics; Space Administration; and, National Science Foundation. Source: https://www.nsf.gov/statistics/srvyfedfunds/#sd (last accessed on 15/10/2019).

[4] United States Census Bureau – Economic Annual Surveys – Geography Area Series: County Business Patterns by Employment Size Class. Source: https://www.census.gov/programs-surveys/cbp.html

[5] Intramural performers are the agencies of the Federal Government. Their work is carried on directly by agency personnel. Conversely, extramural performers are organizations outside the Federal sector that perform R&D with Federal funds under contract, grant, or cooperative agreement.

Table 1: Set of R&D explanatory variables

Intramural and FFRDCs	*Industrial firms*
$l\_INTRA\_R\&D_{rt} = log(INTRA\_R\&D_{rt})$	$l\_IND\_R\&D_{rt} = log(IND\_R\&D_{rt})$
Universities and colleges	*Other non-profit institutions*
$l\_UNIV\_R\&D_{rt} = log(UNIV\_R\&D_{rt})$	$l\_OTH\_R\&D_{rt} = log(OTH\_R\&D_{rt})$

Econometric specifications

The goal is to estimate how relatedness and R&D funds influence technological change at the state level, consistently with the aforementioned hypotheses. Therefore, the emergence of new RTAs on their degree of relatedness are regressed with the technological portfolio of states, which is given by the regional capability match, and on a set of variables capturing the magnitude of R&D funding. Hence, the full econometric estimation (Model 1) to be estimated can be written as follows:

$$ENTRY_{irt} = \alpha + \beta_1 CM_{irt-1} + \beta_2 l\_R\&D_{rt-1} + \beta_3 SPEC_{rt-1} + \beta_4 E_{rt-1} + \varphi_r + \psi_t + \epsilon_{irt}$$

where the dependent variable $ENTRY_{irt}$ is equal to 1 if a technology *i* that did not belong to the technological portfolio of the state *r* in time $t-1$ enters its technological portfolio in time t, and to 0 otherwise. The first key explanatory variable CM_{irt} indicates how the potential new technology *i* is related to the pre-existing technological set of capabilities of state *r*. The second key explanatory variable $l\_R\&D_{rt}$ is the log-transformed amount of R&D funds granted by US Federal Agencies to state r in time $t-1$.

The full model specification considers also two control variables. First, the variable *technological specialization,* $SPEC_{rt-1}$, has been measured by the average location quotient weighted by the number of patents:

$$SPEC_{rt-1} = \sum_i \frac{P_{irt-1}}{P_{rt-1}} LQ_{irt-1}$$

where LQ_{irt-1} is the location quotient of patent application in class *i* in the state *r* and in time $t-1$. The main hypothesis concerning this variable is that highly specialized states are less likely to acquire new RTAs. Moreover, the population size of states is controlled, employing the variable E_{rt-1}.

Finally, φ_r is a state-fixed effect, ψ_t is a time-fixed effect, and ϵ_{irt} is a regression residual.

An alternative model (Model 2) has been estimated considering the set of four R&D funded recipients instead of the total amount:

$$ENTRY_{irt} = \alpha + \beta_1 CM_{irt-1} + \beta_2 l\_INTRA\_R\&D_{rt-1} + \beta_3 l\_IND\_R\&D_{rt-1} + \beta_4 l\_UNIV\_R\&D_{rt-1} + \beta_5 l\_OTH\_R\&D_{rt-1} + \beta_6 SPEC_{rt-1} + \beta_7 E_{rt-1} + \varphi_r + \psi_t + \epsilon_{irt}$$

with the same specifications outlined above.

Therefore, the baseline econometric model was used is a two-way fixed effects model, to take into account omitted variable bias at the state level, assuming that these omitted variables are constant over time. The equation is estimated by using a logit probability regression, with fixed effects by including dummy variables for each state and period composing the dataset. Logistic regressions are useful for situations where there could be an ability to predict the presence or absence of a specific outcome, based on values of a set of predictor variables. It is similar to a linear regression model but is suited to models where the dependent variable is dichotomous, as in this case.

The final dataset consists of data for 51 states (including District of Columbia), 643 technologies (patent technological classes at the 4-digit level) over the period of 1981–2010. Data are averaged over non–overlapping 5-year periods (1981-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2005, 2006–2010), denoted by *t*. To avoid potential endogeneity issues, all the independent variables are lagged by one period, so that we have five observations per state–technology pair, resulting in a balanced panel with 163.965 observations. Different specifications of the two models have been run to validate the hypotheses formulated.

2.6 EMPIRICAL RESULTS

This section presents the econometric results of the impact of relatedness at the state level on technological change in US from 1981 to 2010. Before that, a brief description of the evolution and the distribution pattern of the variables is presented in the following. Figures from 1 to 5 show the evolution of four variables: total number of entries of new related (top left) and unrelated (lower left) RTAs, regional coherence (top right), total R&D funds provided by US Federal Agencies (lower right).

As expected, higher values can be found at the beginning of the survey, since the variables score unitary values in correspondence with the first time a technology class shows a RTA > 1 in a specific state, and 0 for all the other years. This is expected to occur in the first periods of the survey. Although this conclusion holds for both related and unrelated entries, the two variables evolve at a slight different pace: the former decrease relatively slowly and tend to remain stable over time for the vast majority of the states; the latter fall in value quite sharply, with just few exceptions. This is consistent with the evolution of the variable $SPEC_{rt-1}$, which markedly lowers its values over the periods considered (Fig. 6). A straightforward interpretation is that states witnessing more entries of new RTAs progressively reduce their degree of overall specialization, i.e. their knowledge base becomes more diversified. As a general note, regions showing higher values of entries in the first periods (e.g. California, Washington, Texas, Florida) have been gradually caught up by lagging regions (e.g. Nevada, West Virginia), and both the groups tend to stabilize over time. Conversely, the values of the variable *coherence* slightly increase over time for all states, notwithstanding the little fluctuations registered over its mean value (0,04852). Hence, diversification processes do not occur randomly over the technology space, but tend to be related to the portfolio of specializations of the states, thus increasing their internal relatedness. Different conclusions can be drawn here, as the variable shows a relative stable temper over time and tend to regularly award the 'usual suspects': the states hosting Federal Agencies (District of Columbia, Maryland, New Mexico) plus California and Massachusetts. However, values tend to decrease over time, and this is a long-running tendency for the United States. As shown in Fig. 7, the federal share of national R&D funding peaked at 69% in 1964, at which point industry was providing 31% of all R&D funding in the country. Over the next several decades there was an R&D funding reversal during which the industry sector supplanted the federal government as the primary source of funding for the nation's R&D activities. Industry's share of the R&D funding total steadily rose from 31% in 1963 (its low point in the available time series) to about one-half of total in 1980, and then climbed to a high of 69% of total in 2000. The industry's funding share has since edged downward, to 62% of total in 2009.

Table 2: Summary statistics

Dataset 1: All entries						
Variables	Min	1st Quart.	Median	Mean	3rd Quart.	Max
ENTRY	0	0	0	0.0963	0	1
CM	-1	-0.156192	-0.003806	-0.029647	0.136278	0.968290
l_R&D	4.077	5.112	5.607	5.627	6.190	7.233
l_INTRA_R&D	3.194	4.455	4.862	4.927	5.417	6.694
l_IND_R&D	2.808	4.375	5.188	5.096	5.835	6.946
l_UNIV_R&D	3.715	4.561	5.067	5.039	5.453	6.746
l_OTH_R&D	1.988	3.445	4.093	4.083	4.712	6.115
SPEC	1.204	2.230	4.215	15.564	9.350	679.210
E	5.287	5.793	6.206	6.160	6.458	7.208
Observations (N) = 163965						

Dataset 2: Related entries

Variables	Min	1st Quart.	Median	Mean	3rd Quart.	Max
ENTRY	0	0	0	0.1053	0	1
CM	0.000004	0.065791	0.138360	0.170849	0.242051	0.968290
l_R&D	4.077	5.112	5.586	5.583	6.093	7.233
l_INTRA_R&D	3.194	4.451	4.806	4.874	5.285	6.694
l_IND_R&D	2.808	4.425	5.146	5.054	5.765	6.946
l_UNIV_R&D	3.715	4.561	5.049	5.003	5.419	6.746
l_OTH_R&D	1.988	3.445	4.066	4.033	4.584	6.115
SPEC	1.204	2.382	4.352	13.432	9.350	679.210
E	5.287	5.793	6.195	6.151	6.448	7.208
Observations (N) = 80852						

Dataset 3: Unrelated entries

Variables	Min	1st Quart.	Median	Mean	3rd Quart.	Max
ENTRY	0	0	0	0.08759	0	1
CM	-1	-0.2878689	-0.1533729	-0.2246880	-0.0696680	-0.0000002
l_R&D	4.077	5.130	5.643	5.669	6.271	7.233
l_INTRA_R&D	3.194	4.462	4.911	4.979	5.524	6.694
l_IND_R&D	2.808	4.375	5.225	5.138	5.907	6.946
l_UNIV_R&D	3.715	4.580	5.082	5.073	5.520	6.746
l_OTH_R&D	1.988	3.446	4.115	4.132	4.798	6.115
SPEC	1.204	2.161	4.171	17.638	9.346	679.210
E	5.287	5.777	6.222	6.169	6.471	7.208
Observations (N) = 83113						

Tables 2 presents the summary statistics of the variables employed in the econometric estimations. As outlined previously, the acquisition of a new specialization is a rather rare phenomenon, which explains the low mean value of the entry variable (0,09631). The value is slightly higher for related entries (0,1053) than for unrelated ones (0,08759), meaning that related diversifications are relatively more frequent. This result is consistent with the expected behaviour of the variable. Hence, on average, a state has 9,6% probability to acquire a RTA in a new technology class, and, specifically, a 10,53% probability to witness a related diversification compared to 8,76% of witnessing an unrelated diversification. In general terms, the capability match index is rather low throughout the states, with a negative mean value of -0,0296 and 75% of values below 0,1363. With respect to R&D funds, the total amount of federal funds per capita (in log) ranges from 4,077 to 7,233, i.e. (in dollars) from $ 58,97 p.c. to $ 1.384,37 p.c., the mean value being € 277,83 p.c. This is saying that the US Government has spent, on average, less than € 300 a year for every taxpayer. The most awarded category is 'industrial firms', with a mean value of $ 163,37 p.c., and the least one is 'other non-profit institutions', with a mean value of $ 59,32.

Table 3: Entries of new RTAs in the United States (1981-2010) – Total Entries – Model 1

Total Entries	Spec. 1	Spec. 2	Spec. 3	Spec. 4 (Full model)
CM_{irt-1}	0.608898 ***	0.609456 ***	0.5773487 ***	0.5751709 ***
$l\_R\&D_{rt-1}$		-0.122729 .	-0.1870716 **	-0.1812981 *
$SPEC_{rt-1}$			-0.0073010 ***	-0.0070673 ***
E_{rt-1}				-1.1254392 ***
Intercept	-1.719960 ***	-0.990306 *	-0.4055631	6.5129189 **
State F.E.	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes
AIC	102167	102166	101928	101918
N	163965	163965	163965	163965
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Table 3 presents the results for the estimation of the first equation. The model regresses toward the entry of a given technology in a given state on a set of variables: the technological relatedness of the state, the total amount of R&D funds granted by US Federal Agencies, the technological specialization and the total employment of the state (all lagged by one period). The columns present the estimation results derived from adding one variable at a time (left to right), with the last column providing the coefficient estimates from the full model. In all the different specifications, the capability match index has a positive and significant effect with P < 0,001 level. It indicates that technological relatedness has been a crucial driving force behind the evolution of US between 1981 and 2010. Moreover, as expected, the results seem not to be affected by omitted variable bias. Actually, the control variables $SPEC_{rt-1}$ e E_{rt-1} play a significant role on the entry of new technologies. The results also confirm the idea that those states characterized by a very specialized technological structure (technological specialization) are less prone to technological change. Hence, these findings firmly corroborate *Hp1*.

On a less bright note, the variable $l\_R\&D_{rt-1}$ does not show a significant correlation with the dependent variable. Although further implications of this finding will be clearer in the following, at this stage we cannot infer that R&D has a meaningful effect on the construction of new RTAs. Therefore, *Hp2* is not supported.

Table 4: Related vs. Unrelated Entries – Model 1

Related Entries	**Spec. 1**	**Spec. 2**	**Spec. 3 (Full model)**
CM_{irt-1}	-0.090611	0.1068464	0.1031986
$l\_R\&D_{rt-1}$	-0.172456 .	-0.2313171 *	-0.2229054 *
$SPEC_{rt-1}$		-0.0111825 ***	-0.0109038 ***
E_{rt-1}			-1.3053949 **
$Intercept$	-0.796624	-0.1862971	7.8285658 **
$State\ F.E.$	Yes	Yes	Yes
$Time\ F.E.$	Yes	Yes	Yes
AIC	53651	53453	53447
N	80852	80852	80852
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Unrelated Entries	**Spec. 1**	**Spec. 2**	**Spec. 3 (Full model)**
CM_{irt-1}	1.33006 ***	1.2253850 ***	1.2211599 ***
$l\_R\&D_{rt-1}$	-0.03415	-0.0886366	-0.0875884
$SPEC_{rt-1}$		-0.0028894 ***	-0.0028241 ***
E_{rt-1}			-0.8742460 .
$Intercept$	-1.14316 .	-0.7573119	4.6396336
$State\ F.E.$	Yes	Yes	Yes
$Time\ F.E.$	Yes	Yes	Yes
AIC	48322	48295	48293
N	83113	83113	83113
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

To test *Hp3*, the model has been run separately for related and unrelated entries. Again, the results summarized in Table 4 do not validate the assumption that the total amount of R&D funds affects differently the probability of a state to acquire a new RTA, as the correlation is not significant in the first specifications of the model and negative ($P < 0{,}05$) in the last one. Therefore, also *Hp3* cannot be confirmed.

Table 5: Entries of new RTAs in the United States (1981-2010) – Total Entries – Model 1

Total Entries	**Spec. 1**	**Spec. 2**	**Spec. 3**
CM_{irt-1}	0.607452 ***	0.5772643 ***	0.5750712 ***
$l\_INTRA\_R\&D_{rt-1}$	0.045729	-0.0292347	-0.0259046
$l\_IND\_R\&D_{rt-1}$	-0.120763 ***	-0.1237318 ***	-0.1202909 ***
$l\_UNIV\_R\&D_{rt-1}$	0.378192 **	0.4138061 **	0.4789205 ***
$l\_OTH\_R\&D_{rt-1}$	0.183452 ***	0.0750937 .	0.0568587
$SPEC_{rt-1}$		-0.0070414 ***	-0.0068299 ***
E_{rt-1}			-1.2036277 ***
Intercept	-3.855034 ***	-2.9621596 ***	4.1953345 *
State F.E.	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes
AIC	102134	101916	101904
N	163965	163965	163965
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Finally, the econometric estimations of the second equation (Model 2) are displayed in Table 5. Here, the regressor $l\_R\&D_{rt-1}$ has been replaced by its partial values corresponding to four recipient categories. As expected, the coefficients and their signs change dramatically as compared to the first model. While the coefficient of the capability match maintains its significant and positive value, the set of R&D regressors show very contrasting values: while funds granted to intramural and other non-profit institutions do not show any significant correlation with the entry variable, the funds granted to industrial firms have a negative and significant value (in the full model specification equals to -0,12029) whereas the ones granted to universities and colleges have a positive and significant value (in the full model specification equals to 0,47892). Therefore, funding universities and colleges significantly and positively impact the probability of a state to acquire a new RTA (vice versa for funds granted to industrial firms). This behaviour of the variables is consistent with *Hp2a* and, for what concerns one of the non-industrial actors, also with *Hp2b*.

Table 6: Related vs. Unrelated Entries – Model 2

Related Entries	**Spec. 1**	**Spec. 2**	**Spec. 3 (Full model)**
CM_{irt-1}	-0.073616	0.1089238	0.1048787
$l\_INTRA\_R\&D_{rt-1}$	0.152983	0.1007615	0.1174206
$l\_IND\_R\&D_{rt-1}$	-0.133498 **	-0.1309594 **	-0.1257166 **
$l\_UNIV\_R\&D_{rt-1}$	0.075369	0.1114715	0.1463419
$l\_OTH\_R\&D_{rt-1}$	0.238944 ***	0.0913750	0.0702417
$SPEC_{rt-1}$		-0.0108618 ***	-0.0106345 ***
E_{rt-1}			-1.2874508 **
Intercept	-3.247484 ***	-2.2991089 *	5.4499595 .
State F.E.	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes
AIC	53633	53454	53449
N	80852	80852	80852
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Unrelated Entries	**Spec. 1**	**Spec. 2**	**Spec. 3 (Full model)**
CM_{irt-1}	1.331460 ***	1.230695 ***	1.2264512 ***
$l\_INTRA\_R\&D_{rt-1}$	-0.048632	-0.104007	-0.1155216
$l\_IND\_R\&D_{rt-1}$	-0.086383	-0.097957 .	-0.0953995 .
$l\_UNIV\_R\&D_{rt-1}$	0.722846 ***	0.721869 ***	0.8135334 ***
$l\_OTH\_R\&D_{rt-1}$	0.050346	0.009525	-0.0078467
$SPEC_{rt-1}$		-0.002849 ***	-0.0027772 ***
E_{rt-1}			-1.1888894 **
Intercept	-4.285363 ***	-3.680698 ***	3.3439951
State F.E.	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes
AIC	48309	48283	48278
N	83113	83113	83113
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Similar conclusions can be drawn for *Hp3a* and *Hp3b*, as shown in Table 6. Most notably, the coefficient associated with $l\_UNIV\_R\&D_{rt-1}$ almost doubles its value when estimated with respect to unrelated entries (from 0,47892 of the previous specification to 0,81353). Conversely, its effect on related entries is positive but not significant. Finally, $l\_IND\_R\&D_{rt-1}$ keeps its significant and negative value in both related and unrelated diversification.

The coefficients of a logistic regression do not have a straightforward economic interpretation, which therefore requires the estimation of the odds ratios (OR). Table 7 shows the ORs for the first equation estimated (full model). The OR of 1,78 for the capability match means that a 1-unit change in the level of relatedness for a given technology in a given state increases the probability of the entry of this technology in this state during the next period by about 77% in the full specification. The economic impact of relatedness remains stable across the different econometric specifications. With respect to the OR of the R&D funds granted to universities and colleges, its value of 1,61 means that a 1-unit change in the amount of funds granted increases of 61% the entry probability of a new technology. In economic terms, this entails that by doubling the average p.c. funds granted to universities and colleges (from $ 154,32 to $ 308,64), a state will have an increase of 35% in the probability to acquire new RTAs.

Table 7: Odds Ratio – Model 2

Variables	OR (Total entries)	OR (Related entries)	OR (Unrelated entries)
CM_{irt-1}	1.7772570	1.1105759	3.4091099
$l\_INTRA\_R\&D_{rt-1}$	0.9744281	1.1245923	0.8909013
$l\_IND\_R\&D_{rt-1}$	0.8866625	0.8818648	0.9090097
$l\_UNIV\_R\&D_{rt-1}$	1.6143308	1.1575919	2.2558648
$l\_OTH\_R\&D_{rt-1}$	1.0585062	1.0727674	0.9921840
$SPEC_{rt-1}$	0.9931934	0.9894219	0.9972266
E_{rt-1}	0.3001035	0.2759734	0.3045593

2.7 CONCLUDING REMARKS

In this work, evidence was provided that the evolution of technological knowledge, as defined by the entry of patent technology classes in states, is conditioned by the existing technological knowledge base of states. These findings are consistent with the evidence gathered by the vast majority of scholarly work on the subject (Neffke et al., 2011; Boschma et al., 2013; Fan & Lang, 2000; Breschi et al., 2003; Boschma et al., 2015; van den Berge & Weterings, 2014). The analysis of the evolution of patent portfolio of the 51 United States during the period of 1981-2010 delivers the meaningful conclusion that a new technology is more likely to enter a state when technologically related to other technologies in that state. These results indicate that technological relatedness has been a driving force behind technological change in the United States, and that the long-term evolution of the technological landscape is subject to path dependence.

More importantly, the hypothesis that public incentives for R&D activities have a positive impact on the probability of a state to acquire new RTAs seems to be confirmed, but controversial evidence has been gathered. While R&D funds granted to industrial firms negatively impact on the entry probability of a new technology at the state level, funds granted to universities and colleges have a positive and significant effect. As stated earlier, industrial R&D is mainly dominated by large firms, which are more likely to be subsidized for financing further exploitation of existing technologies, with detrimental effects on regional diversification (Frenken, 2017). Conversely, funding to academic bodies spurs the exploration of new technological trajectories, especially in unrelated domains. At the aggregate level, the impact of R&D funds is not significant, which could explain the poor evidence gathered in recent studies (see Broekel & Mewes, 2017).

A supplementary outcome of this analysis is that the impact of regional capability match is significant also for unrelated entries. This is actually consistent with Xiao et al. (2018) that showed how core knowledge and manufacturing regions rely less on relatedness as driver of diversification, as compared to lagging regions. These findings call for further research in this direction. For instance, does the impact of relatedness change with respect to advanced and lagging regions? And, consequently, do R&D positively or negatively moderate the impact of relatedness with respect to advanced and lagging regions? From a geographical perspective, it would be also interesting to investigate where unrelated and related diversification occur thanks to the provision of above-average public funds.

A major shortcoming of this analysis is that it couldn't measure the effect of R&D funding to specific technological classes. This is mostly due to the shortage of data, but can be easily overcome by employing research collaborations data. Also, further specifications of the econometric model, as duration models, seem more apt to capture the effect of relatedness and R&D funds, but their adaptation to panel data is not straightforward (Verbeek, 2008). Finally, the scale of analysis should be narrowed, as diversification processes are better investigated below the state level.

A final issue deserves attention in future research. This paper has explored the extent to which the entry of a new technology depends on the amount of public funds granted for R&D activities, yet neglecting other innovation policies, at the state level, that might be crucial in the process of technological diversification, and the institutional conditions at the state level (Frenken, 2017).

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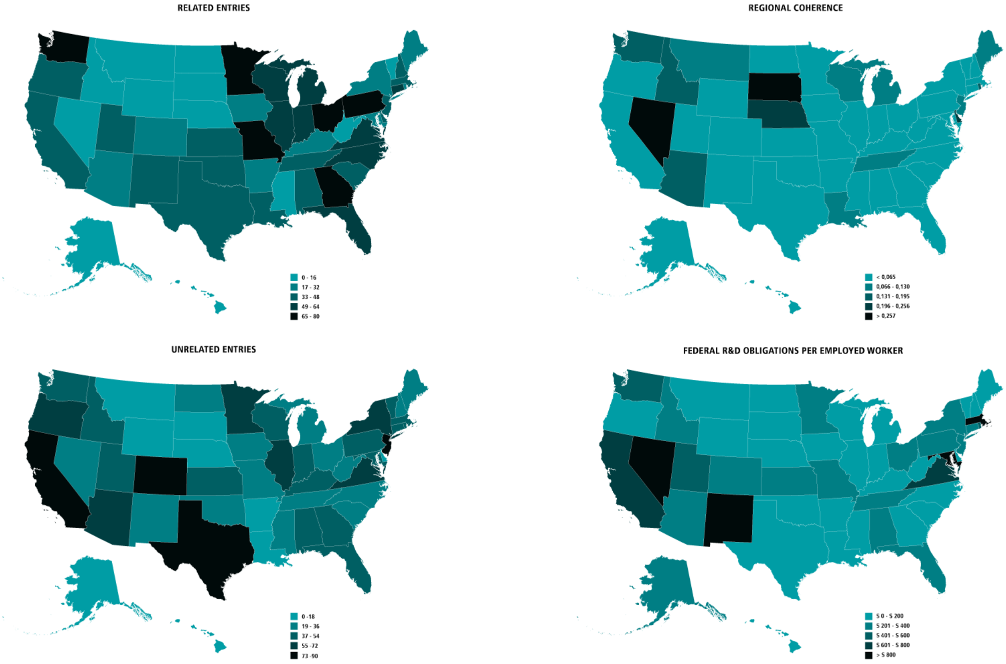

Figure 1: Related and Unrelated Entries (1986-1990), Regional Coherence and Total Federal Funds for R&D (1981-1985)

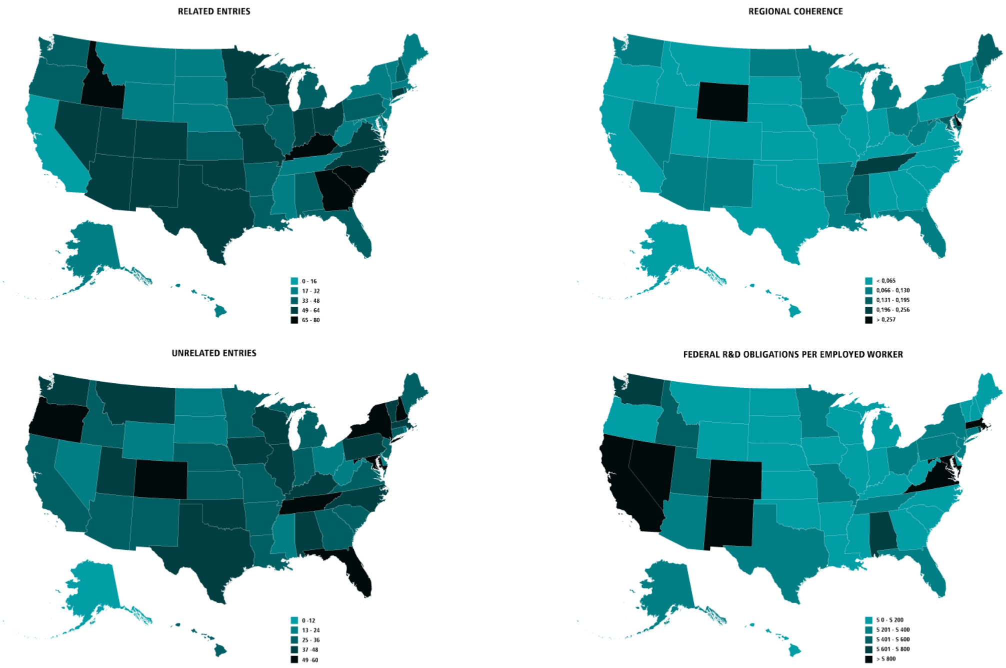

Figure 2: Related and Unrelated Entries (1991-1995), Regional Coherence and Total Federal Funds for R&D (1986-1990)

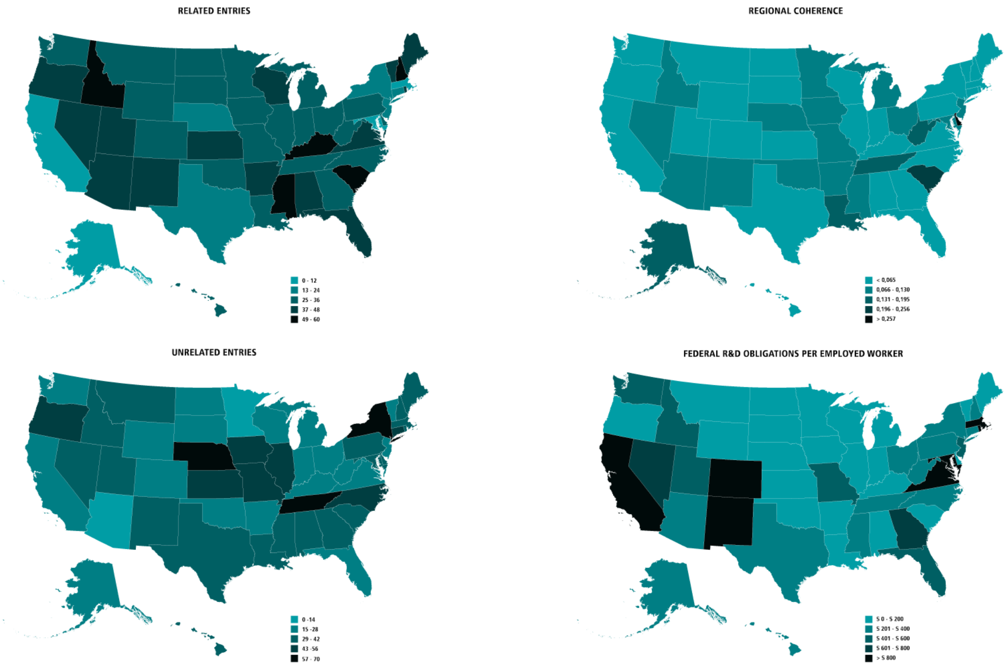

Figure 3: Related and Unrelated Entries (1996-2000), Regional Coherence and Total Federal Funds for R&D (1991-1995)

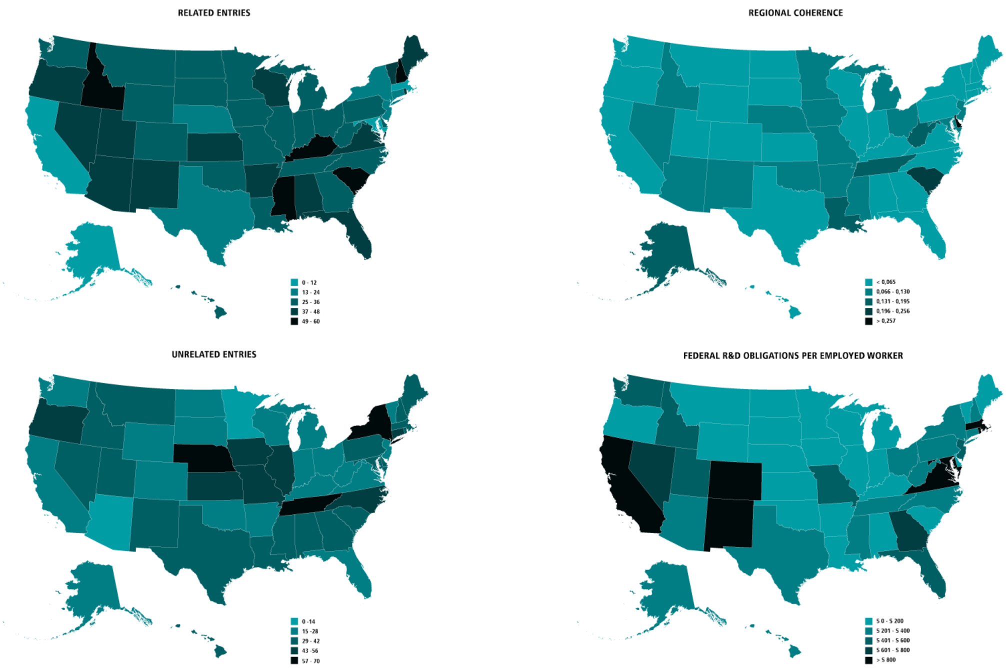

Figure 4: Related and Unrelated Entries (2001-2005), Regional Coherence and Total Federal Funds for R&D (1996-2000)

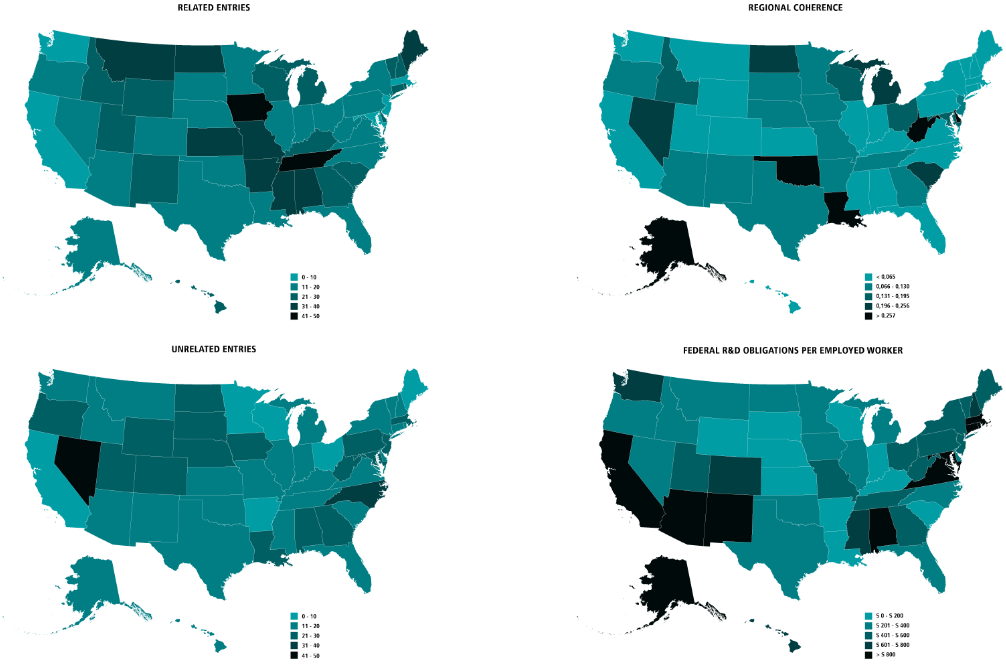

Figure 5: Related and Unrelated Entries (2006-2010), Regional Coherence and Total Federal Funds for R&D (2001-2005)

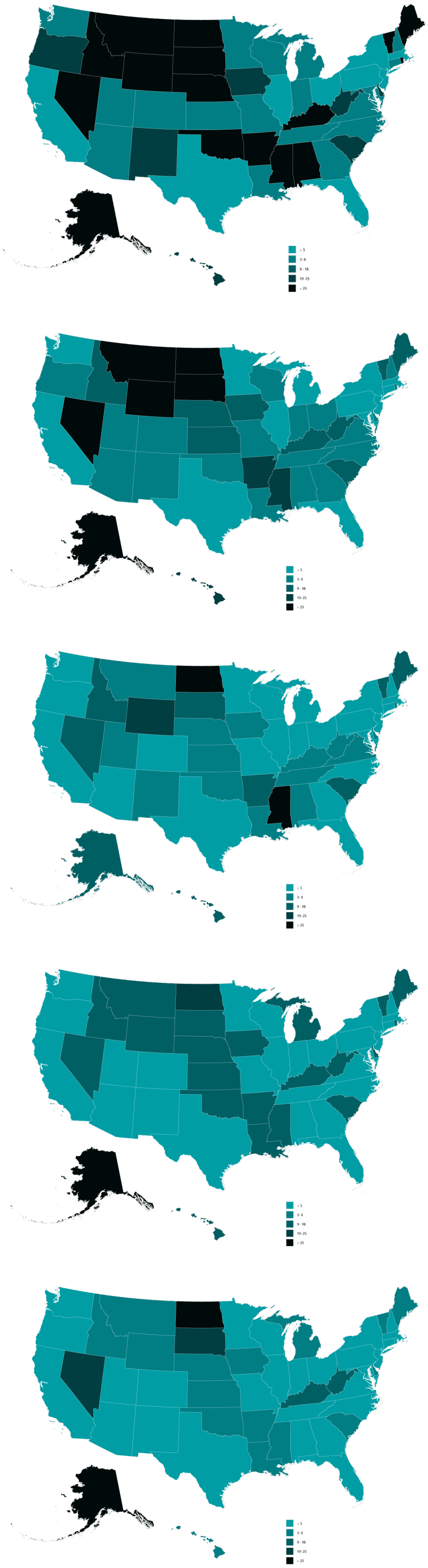

Figure 6: The evolution of Technological Specialization in the United States (1981-2000)

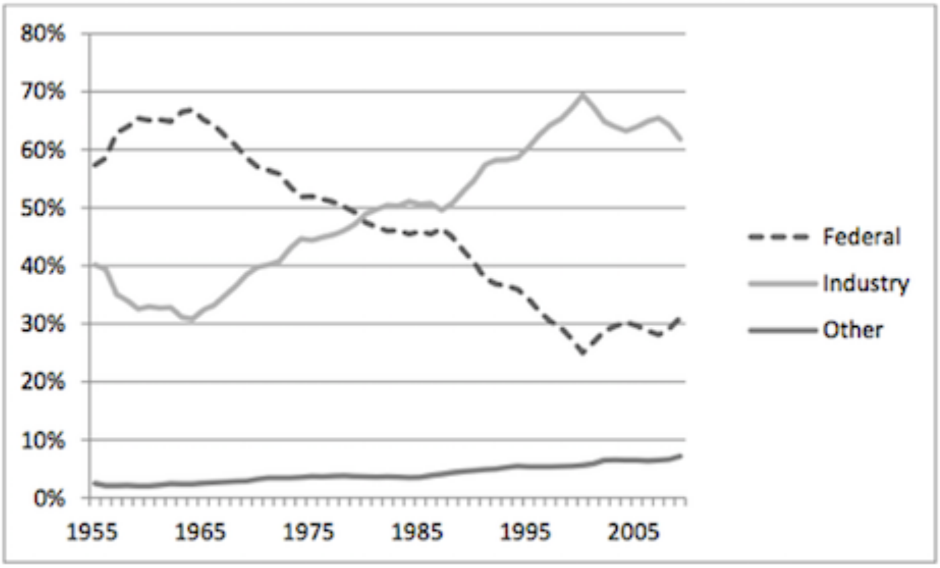

Figure 7: National R&D Expenditures, by Source of Funds Percent. Source: National Science Foundation

3. DOES RELATED VARIETY MATTER FOR CREATIVE EMPLOYMENT GROWTH?

by ANDREA SIMONE

ABSTRACT

Little progress has been made in the mitigation of the controversies surrounding creativity and its role for local economic development (Florida, 2002; Peck, 2005). Moreover, creative industries seem to have been denied, so far, a prominent role in the intense debate about the impact of localization or urbanization economies on innovation and growth. Taking departure in the void between these two streams of literature, I deploy the concept of «related variety», as formulated by Boschma (2005) and Frenken, van Oort and Verburg (2007), to verify if well-diversified and interdependent creative industries determine more pronounced local creative employment growth. A pooled OLS panel model has been estimated for 73 Italian provinces (2008-2010), using the total amount of creative workers as dependent variable and the variety indexes as main regressors. The results are mostly consistent with the main hypothesis: related variety, in terms of complementarity between sectors, has a positive and significant effect on provincial creative employment growth.

KEYWORDS: creative industry, related variety, Italian provinces.

3.1 INTRODUCTION

Human creativity has been largely acknowledged as a powerful engine in driving economic growth. This perspective has been extensively developed in Richard Florida's seminal contribution *The Rise of The Creative Class* (2002), where urban growth has been mostly related to the capability of cities of cultivating and attracting creative and talented workers. Nevertheless, the «creativity debate» has increasingly run aground by being couched in terms of an either/or choice: on the one hand, an unquestioned faith in a «high-road path to sustainable prosperity» (Florida, 2002); on the other, the general fear of a growing supremacy of «interurban competition, gentrification, middle- class consumption and place marketing» (Peck, 2005) against redistributive spending and social programming. The more the debate lingers, the more irreconcilable and hardened these conflicting views are likely to become.

Florida's fuzzy definition of creative class (Markusen, 2006) is, indeed, one of the main shortcomings of his theory and pushes the concept of creativity away from its original field of application, thus allowing for a number of potential misinterpretations: what do we actually mean by «creative class»? How can we reasonably claim that a causal logic may exist in the relationship between creativity and economic growth? While scholars have been engaging with «creativity» in terms of human factor and its creative habitat for quite some time, little attention has been recently paid on «creative industries», and specifically on «core cultural activities» and their role for local economic development. There is a growing consensus, indeed, that specific strengths in the creative industries area may allow local economies to gain a competitive advantage at a broader socioeconomic level, in terms of innovation production and cross-sectorial knowledge transfer (Rutten, Marlet, & van Oort, 2011). Then, rather than investigating the residential choices of high-skilled creative workers, we should focus on the reasons why creative industries flourish in specific places and not in others. It is precisely this kind of analysis that is of particular interest here and sets the framework for a potential reconciliation attempt between conflicting visions of creativity.

Most notably, creative industries seem to have been denied, so far, a prominent role in the intense debate about the impact of localization or urbanization economies on innovation and growth, which is usually referred to as «Marshall vs. Jacobs' externalities». Recently (Frenken et al., 2007; Boschma & Iammarino, 2009), a more accurate definition of «Jacobs externalities» has been proposed, which distinguishes between «related variety», which occurs when there are complementarities among sectors in terms of shared competences, and «unrelated variety», which covers sectors that do not share complementary competences. Boschma & Iammarino (*ibidem*) gathered strong evidences about the influence of different kinds of variety for manufacturing industries, but a similar contribution for the cultural and intellectual activities is still missing. We follow up with their methodological approach to help filling this gap.

The research question underlying the analysis is roughly the following: do creative industries, in terms of employment growth, benefit from variety? I have tried to answer this question by focusing on a small number of creative activities, selecting five three-digit groups within the NACE Rev. 2 system: cinema (JA591), music (JA592), photography (MC742), art (RR900) and cultural activities (RR910). The main hypothesis underlying the analysis is that higher levels of related variety within creative industries determine more pronounced local creative employment growth. But I also wanted to test if unrelated variety plays any role in this scenario, as one might expect, given its *portfolio effect* for the whole economy, especially during recessions (Frenken et al., 2007). This is why I set the time frame of the analysis to the outbreak of the last economic crisis (2008-2010).

The paper is divided into four parts. After this introduction, Section 2 gives a quick overview of the two streams of literature respectively referring to the creative industry's debate (Section 2.1) and the Jacobs vs. Marshallian externalities (Section 2.2). In the further sections I will briefly discuss the methodological approaches undertaken in the evaluation of the influence of related and unrelated variety on employment dynamics, I will present the data collected, the empirical model and the econometric estimations (Section 3), with some final comments (Section 4).

3.2 THEORETICAL FRAMEWORK

3.2.1 The rise of the creative industry

As is well known, the emergence of a new phase of capitalistic development, which has been typified in terms of «new economy» (Beyers, 2003), «knowledge economy» (Cooke & Piccaluga, 2006), «cognitive capitalism» (Moulier Boutang, 2007), has increasingly blurred the boundaries of what we usually associate with the term «creative activities» and has led to an enormous expansion of jobs that rely upon the diverse cognitive and cultural capacities of workers (Scott, 2011). This is why «creative industry» has gradually become a slippery concept among scholars. The list of activities that fall under this definition has increased dramatically over the years: marketing, advertising, broadcasting, industrial design, interactive leisure software, research and development (Howkins, 2001; Hesmondhalgh, 2002), just to mention a few, they all seem to fulfil the «admission criteria», though a commonly accepted list is still missing. The emergence of this new taxonomy does not pose, *per se*, any threat of ambiguity in our understanding of the phenomenon, but it is likely to jeopardize the way we assess it. A number of preliminary questions arise: can «creative industries» be considered as an evolution of cultural industries or do they significantly diverge from each other? How can we define «core» creative industries as opposed to the «newcomers»? And, eventually, is it still worth assessing them specifically in regional studies and why?

The answer to question one is not straightforward. First of all, the term «creative industry» is relatively recent and it emerged primarily as a policy-related concept (Flew & Cunningham, 2010). The shift from «culture» to «creativity» is emblematic of a new trend in public policy-making that had been moving, since the 1970s, «from a supply-side, artist-centered approach to one that gave stronger consideration to consumer demand and cultural markets» (*ibid*., p. 120). For the last two decades, as said above, creativity has been increasingly given a central role in the generation of economic growth and cultural policy has started to be perceived «as an essential component in any respectable economic policy-maker's development strategy» (Throsby, 2008, p. 229). Much of the reluctance to consider the terms «creative industry» and «cultural industries» as interchangeable comes from distinctive national traditions and different policy routines in understanding these categories and it may be lessened using a «concentric circles» approach (*ibidem*), «where industries are distinguished by the «core» role given to creativity in the input stage of production» (Flew & Cunningham, 2010, p. 116). For instance, «the visual arts would be seen as a "core", but advertising would be seen as more "peripheral" as it combines creative inputs with other inputs» (*ibidem*). Working definitions of «creative industries» seem to be less problematic. The development of the revised UNESCO's *Framework for Cultural Statistics* (UNESCO, 2007) provided a major contribution in this direction, endorsing the inclusion of the following sectors into the creative industry: publishing and literature; performing arts; music; film, video and photography; broadcasting (television and radio); visual arts and crafts; advertising; design (including fashion);

museums, galleries, and libraries; interactive media (web, games, mobile, etc.). However, other operational definitions provided by national or international bodies like DCMS or UNCTAD are equally widespread. So, there is no single correct answer to question 2: the line of demarcation between «core» creative industries and «peripheral» ones will shift in relation to specific contexts, methodological approaches and goals pursued. Nevertheless, a specific focus on core creative activities is still needed. One might claim indeed, referring to question 3, that nowadays every job calls for more creativity than in the past and creative industry may simply count as another sector, perhaps the most relevant, but just «one among many» in an increasingly knowledge-based economy. In this guise, «creativity» rather «creative industry» should be the focal point of our analysis and a theoretical approach of that kind is undoubtedly consistent with the well-established literature about the role of human capital on economic growth and long-term prosperity (Uzawa, 1965; Lucas, 1988; Kotkin, 2000; Florida, 2002). But there is a growing consensus that the creative industry *per se* may be seen as a «flywheel» of local economic development (Cooke & Lazzeretti, 2008) and that specific strengths in the creative industries area may allow local economies to gain a competitive advantage at a broader socioeconomic level, in terms of innovation production and cross-sectorial knowledge transfer (Rutten et al., 2011). It is precisely this kind of analysis that is of particular interest here and sets the framework for the next relevant issue: where do creative industries flourish and why? A complete answer to this question is far beyond the purpose of this study, but a specific aspect would be stressed in the following sections: in which measure do creative industries benefit from variety? And how can we assess it?

3.2.2 Creative industries and related variety: A missing link

Since Marshall's original speculation (1920), localization economies have been related to a wide range of benefits arising from sectorial specialization of a region, which have been typified, most notably, in terms of knowledge spillovers (Arrow, 1962; Romer, 1987), competitive advantage (Porter, 1990) or localized learning (Malmberg & Maskell, 2006). The flip side of specialization is diversification (Rosenthal & Strange, 2002): Jacobs (1969) stressed the importance of urban diversity for cross-fertilization of ideas, so we usually make use of the term «Jacobs' externalities» to refer to the benefits arising from a relatively diversified local industrial structure. Both kinds of agglomeration economies seem to play a role for creative industries and various studies have attempted to identify the impact of the geographical concentration of creative industries in terms of generation of Marshall or Jacobs' externalities. Two seminal contributions certainly deserve to be mentioned here. First, the contribution given by the «Californian School of External Economies» to the «New Hollywood» debate, in particular Storper (1989) and Scott (2002). In their analysis, Marshallian localization economies have been reinterpreted in terms of transaction costs' theory, but the sources of those positive externalities were still found among classical Marshallian paradigms, such as labour market pooling and «overlapping production networks» (*ibidem*).

Nevertheless, their findings are consistent with the general view that creative industries, at least those highly capitalized and industrialized in their modes of production and distribution (such as film, television, videogame), can benefit from clustering and that, in general, «local buzz» is crucial for creative industry (Storper & Venables, 2004). Even challenging the traditional concept of the Marshallian district and adopting an evolutionary perspective on interfirm networks formation in creative industry, evidences have been gathered that clusters still represent a crucial space of potential interaction between similar firms as their industry evolves (for videogame industry see Balland, De Vaan and Boschma, 2013). On the other hand, it is well known that creative industries necessitate a variegated (or diversified) environment to flourish and some scholars highlighted how variety and urban diversity matter for innovation and knowledge transfer. This perspective has been extensively stressed in the *human capital* debate and finds in Richard Florida's *The Rise of The Creative Class* (2002) its most appealing formulation. Even if Florida shifts the focus from the «creative industries» to the human factor and its creative habitat (Lazzeretti, Capone and Boix, 2012), he undoubtedly succeeds in explaining why some places become poles of attraction for the creative «class» and consequently experience high rates of concentration of creative activities. That is saying, in a nutshell, that the more «variegated» is the creative environment of a place, the more vibrant is the potential cross-fertilization between related activities. But what kind of «variety» does matter? Recently (Frenken et al., 2007; Boschma & Iammarino, 2009), a more accurate definition of «Jacobs' externalities» has been proposed, that distinguishes between «related variety», which occurs when there are complementarities among sectors in terms of shared competences, and «unrelated variety», which covers sectors that do not share complementary competences. While the former is likely to account for the generation of those inter-sectorial knowledge spillovers formerly known as Jacobs' externalities, the latter can be interpreted in terms of *portfolio effect*, that is the capability of a local economy to absorb sector-specific shocks and thus dampen the detrimental effects of the crisis for the whole economy (Boschma & Iammarino, *ibid*.). Related variety seems to fit better the idea that knowledge can actually spill over from one firm to another: any knowledge transfer, in this guise, is likely to occur only when there is a real interaction potential between the two firms. And this is quite straightforward. Paraphrasing Boschma & Iammarino (*ibid*., p. 292): «It is unclear what a pig farmer can learn from a microchip company even though they are neighbours». So a certain degree of «cognitive proximity» (Boschma, 2005) is needed, but not too much: risks of cognitive lock-ins might counter-balance, indeed, the beneficial effects generated by specialization. Little attention has also been paid to the dynamics of extra-regional knowledge spillovers, in terms of incoming flows of new knowledge in the region that may arise through different channels: IDEs, trade linkages, global production chains, etc. (Boschma & Iammarino, 2009). Similar remarks apply there: a region may benefit from the inflow of external knowledge if it is neither too distant (lacking absorptive capacity) nor too close (risks of crowding-out) to the regional knowledge base. Strong evidence has been gathered about the influence of different kinds of variety for manufacturing activities, but very few studies try to assess it for the creative industry. The analysis carried out in this paper starts from this final remark.

3.2.3 Research questions

The purpose of the present work was to examine the impact of related and unrelated variety on creative employment dynamics in Italian provinces (NUTS3) during the outbreak of the economic crisis (2008-2010). The main hypothesis underlying the analysis is that well-diversified and interdependent creative industries determine higher local employment growth rates. However, I claim that the post-2008 economic turbulence was likely to be less harsh for provinces characterized by a high degree of unrelated variety, as it allows local economies to absorb sector-specific shocks and dampen the detrimental effects of the crisis for the whole economy, including creative industry. Therefore, employment rates are generally expected to be more favourable for those provinces. We can summarize the previous statements in the following formulation:

Hypothesis A: *Related variety within creative industry has a direct and positive effect on its employment growth.*

Hypothesis B*: Unrelated variety within all industries has an indirect and positive effect on creative employment growth.*

In line with Boschma & Iammarino (2009), I made use of the provincial trade profiles in order to estimate the sectorial composition of the provinces. This methodological approach allows us to simultaneously test if relatedness between the flows of knowledge brought in the province (imports) and the existent knowledge base (exports) affects positively provincial creative employment. So, the last hypothesis can be formulated as below:

Hypothesis C*: Imports' relatedness with the provincial knowledge base has a direct and positive effect on creative employment growth.*

The study attempts to underpin these hypotheses with empirical evidence.

3.3 THE EMPIRICAL ANALYSIS

3.3.1 The analytical framework

The relation between creative industries' growth and the amount of related variety occurring at provincial level is the main aim of this study. As I pointed above, I made use of the provincial trade profiles in terms of both export and import diversification within the creative industry. The generic assumption is that export profile can usefully reflect the sectorial composition of local economy, whereas imports data can account for the inflow of extra-local knowledge, both related and unrelated, that may be turned into growing opportunities.

Following Frenken et al., (2007), variety has been estimated in terms of entropy index whose value increases the more diversified the export/import profile of a province is. The use of trade data to estimate entropy indexes follows the approach by Boschma & Iammarino (2009) and the analytical framework has been set accordingly. Nevertheless, the peculiarity of the creative industries is not fully compatible with the traditional way relatedness is computed, that is the amount of entropy occurring within a group of three-digits industries sharing the same two-digits. The source of this methodological shortcoming can be traced in the way international industrial classifications (in this case, NACE Rev. 2) have been developed, which are such that creative activities are distributed within a large and composite group of two-digit sectors. Therefore, a strong relatedness between a pair of three-digit industries sharing the same two-digits is often missing (e.g. «photography» shares the same two-digits with «legal activities»). These limitations are less stringent for manufacturing industries. So I adopted a different approach: I endorsed the UNESCO's definition of creative industry and measured the amount of relatedness between the industries belonging to this peculiar category. In this way, we can properly assess the magnitude of the cross-fertilization occurring between different creative activities.

Then, with regard to the indicators, exports' entropy at three-digit level as been assumed to measure the degree of *related variety* within the creative industry in a given province. This index is computed with the following formulation:

$$VARIETY = \sum_{i=1}^{N} p_i \, log_2\left(\frac{1}{p_i}\right)$$

where p_i stands for the share of exports of a specific three-digit activity within the creative industry. The economic meaning is quite straightforward: the more diversified creative industries within a given province are in terms of export profile, the higher is the probability that positive cross-sectorial externalities will occur among them and, consequently, the more the province will benefit from them in terms of creative employment growth (if hypothesis one is true).

Unrelated variety has been estimated in terms of entropy measure at one-digit level for all the industries within a given province. As I pointed out earlier, I expected that high levels of unrelated variety could have a positive, though indirect effect on creative employment. The formulation is then the following:

$$UNRVAR = \sum_{i=1}^{N} S_i \, log_2\left(\frac{1}{S_i}\right)$$

where S_i stands for the share of exports of a one-digit industry within the whole provincial economy. With regard to import data, I provided two kinds of indicator:

- *Import variety* which reflects the entropy measure at three-digit level within a given provincial import profile and has been calculated as below:

$$IMPVAR = \sum_{i=1}^{N} k_i log_2 \left(\frac{1}{k_i}\right)$$

  where k_i stands for the share of imports of a specific three-digit activity within the creative industry.The assumption is that highly diversified inflows of extra-provincial knowledge, by means of imports variety, are positively correlated with creative employment within a given province, in so far as they are likely to generate higher cross-sectorial knowledge spillover.

- *Related trade variety*, which has been assumed to reflect the amount of knowledge inflows, within a given province, that are strongly related to a given industry but not strictly belonging to it. In other words, for each three-digit export industry in a given province, I provide the estimation of the imports entropy between the other three-digit industries – $EE(i)$ – excluding the same three- digit import sector. In this guise, I claim that more learning opportunities will occur within a given province if the inflows of extra-provincial knowledge can symmetrically balance the existent knowledge base, preventing the occurrence of crowding-out effects. The indicator has been calculated as below:

$$RELTRADVAR = \sum_{I} EE(i) \cdot X(i)$$

  where $X(i)$ is the relative size of the three-digit export industry.

3.3.2 Data, empirical model and econometric estimation

An operational definition of «creative industry» has been given, selecting five three-digit groups within the NACE Rev. 2 system: cinema (JA591), music (JA592), photography (MC742), art (RR900) and cultural activities (RR910)[1]. The empirical analysis has been carried out for 73 Italian provinces out of a total of 110 provinces. The reasons for excluding some provinces are mostly methodological: the time frame of the analysis is almost coincident with the creation of new provinces for which a large number of statistical indicators are not available until 2010. Other

[1] The restriction to a subset of creative industries, namely the "core cultural industries" (as outlined in § 3.2.1) is mainly due to a shortcoming of export data at levels of detail narrower that 3-digit, where non-core activities (like advertising, tourism, architectural and design services) cannot be detected without including redundant data.

provinces have been excluded because their trade profile within creative industries is nearly insignificant and would have led to misleading results.

I collected data on creative workers using Asia Database (ISTAT), while «Coeweb» ISTAT database has been used to collect trade data. I also collected data on provincial density and the share of young population (21-30 years old) with a university degree.

A pooled OLS panel has been run, using the total amount of creative workers as dependent variable and the relatedness indexes as regressors, controlling as well for provincial population density and share of talented young people. The model is then the following:

$$CREATIVE_{it} = \alpha + \beta_1 VARIETY_{it} + \beta_2 UNRVAR_{it} + \beta_3 IMPVAR_{it} + \beta_4 RELTRADVAR_{it} + \beta_5 GRADUATES_{it} + \beta_6 DENS_{it} + \epsilon_{it}$$

where *CREATIVE* stands for the total amount of creative employees; $VARIETY$, $UNRVAR$, *IMPVAR*, and *RELTRADVAR* have been computed as above mentioned (Sec. 3.1), *GRADUATES* stands for the number of graduates every 1000 inhabitants and *DENS* is population per km2.

The results are mostly consistent with the main hypotheses: related variety, in terms of complementarity between sectors, has a positive and significant effect on provincial employment growth.

Table 1: Econometric results

	Coeff.	**σ**	**t-value**	**p**
$Intercept$	-5803.4057 *	2359.8832	-2.4592 *	0.01473 *
$VARIETY_{it}$	1499.6989 *	734.3779	2.0421 *	0.04238 *
$IMPVAR_{it}$	-46.1916	1331.3045	-0.0347	0.97235
$RELTRADVAR_{it}$	1064.5122	1536.1123	0.6930	0.48907
$UNRVAR_{it}$	4266.3801 *	1852.3950	2.3032 *	0.02224 *
$GRADUATES_{it}$	88.4798	50.3575	1.7570	0.08036
$DENS_{it}$	9.0271 ***	1.0338	8.7318 ***	7.56e-16 ***
Signif. codes	0 (***)	0,001 (**)	0,01 (*)	0,05 (.)
Balanced panel	n = 73	T = 3	N = 219	
R^2	0.34816			
Adj. R^2	0.33703			
p-value	< 2.22e-16			

On average, an increase by 1 of the related variety indicator provokes an increase of nearly 1500 creative workers in a given province. Moreover, unrelated variety shows, as expected, a significant impact on the response variable: when a province has many industries that are unrelated, it can more easily absorb sector-specific shocks and thus dampen the detrimental effects of the crisis for the whole economy, including creative industries. Import variety and related trade variety do not seem to have a significant impact instead.

3.4 CONCLUSIONS

The purpose of the present work was to set the framework for a potential reconciliation attempt between conflicting visions of creative industries. This field of analysis has been increasingly receiving theoretical attention since the seminal contribution of Florida (2002) and scholars have been engaging with cultural industries for all over the last three decades, but the more the debate lingers, the more irreconcilable and hardened the conflicting views are likely to become. The theoretical approach carried out in this paper looks at the bigger picture and focuses on a simple question: why do creative industries flourish in specific places and not in others? A complete answer to this question was far beyond the purpose of this study, but a specific aspect has been stressed here: based on the econometric estimations illustrated above, related variety seems to play a major role for the flourishing of creative industries. High levels of related diversification tends to boost creative employment at provincial level and this was the core assumption of this study. However, in times of economic recession, unrelated variety has a significant, though indirect, effect on creative employment, as pointed out above. This might lead to infer, indeed, that metropolitan areas, which usually have higher level of unrelated variety, are likely to be more resilient when they face economic recessions, but a more accurate assessment of the evidences provided above has still to be undertaken, so any final remark would be imprudent at this point of the analysis.

Finally, it is worth considering two of the main shortcomings of this study. First of all as regards the model estimation carried out. A pooled OLS panel, which generally has the following formulation:

$$y_{it} = a + bx_{it} + \varepsilon_{it}$$

does not control for individual effects, so it is only able to test if relatedness, at different levels, does have *on average* a positive effect on employment growth. Nevertheless, it is well known that individual effects play a relevant role in this relation and better model specifications could be provided. Secondly, the use of provinces' trade profile requires some clarifications with regards to the territorial unit of analysis and the aggregated indicator chosen. Province suffers from two main shortcomings: it might be too large to capture socioeconomic processes of creativity occurring at sub- provincial levels and is affected by a considerable degree of variability in terms of borders and belonging municipalities. The use of Local Labour Markets (LLM) as territorial units of analysis might have been more accurate for the purpose of this study, but a large number of indicators are not easily available at that geographic scale. Nevertheless, provinces are far more adequate than regions to assess creative industries' dynamics given their strong interconnection with the urban context. As regards trade data, their use suffers from some limitations in terms of explanatory power: creative industries are mainly service-based activities and their export capability is relatively low. However, I claim that these limitations are not geographically bound but are mostly sector-specific, therefore we can infer that, in general, the higher the amount of provincial exports that a specific creative industry can generate, the more its relative importance within the considered province is.

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FINAL REMARKS

The work provided both theoretical and empirical evidence of two key drivers of regional diversification. First of all, it remarks the pivotal role played by technological relatedness, in line with several other contemporary studies. The econometric analysis developed in the second paper confirms the hypothesis that relatedness has driven the structural evolution of United States over the period 1981-2010. Moreover, the third paper shows that related variety significantly spurred the growth of creative employment in the Italian provinces between 2008 and 2010. However, unrelated variety had also a significant, though indirect, effect on creative employment, as it helps provincial economies to absorb sector-specific shocks and to dampen the detrimental effects of the economic recession occurring in that period.

Although extensively investigated, relatedness remains a slippery phenomenon for scholars and not easily measurable, so methodological contributions are still precious to the debate. For the purpose of the second paper, I developed a new regional index, following Neffke et al. (2018) but employing patent data. This index can be adapted to a variety of uses, ranging from a policy tool to address public investments in strategic innovation fields, to a predictor of diversification in the region. It also has a straightforward interpretation: values below and above 0 respectively reflect relatedness and unrelatedness at regional level. Hence, it can easily be employed to distinguish among related and unrelated entries of new specialization, as done in this work.

A second key driver of regional diversification is public policy. The role of public policy in shaping regional industrial trajectories has been outlined in the first paper. Most notably, public policies can either reinforce the role of industry relatedness, by assisting regional branching into related sectors, or act disruptively by harnessing existing regional assets and local knowledge into new unrelated activities. This is particular relevant for lagging regions, facing both institutional and economic constraints to catch up with core regions. But it is also relevant for mature and old industrial regions to escape from lock-in in exhausted path trajectories. In fact, in regions where a technological regime is also strongly aligned with localized learning, territorial institutions and vested interests, it's unlikely for a new industry to mark a radical departure from a region's own past in absence of a national or regional strategy. The second paper offers empirical evidence that public incentives for R&D activities have a positive impact on the probability of a state to acquire new RTAs in unrelated domains, especially those incentives awarded to universities and academic institutions. So far, this is the first contribution in the literature that empirically validates this correlation with econometric estimations.

These findings call for further research. On one hand, future analyses should take into account the differences among the economic levels of regions. In fact, the generation of novelty in old industrial regions is more dependent on state-inspired or state-supported action than it is in advanced technology regions, where the evolutionary processes of search and selection are led by knowledge-intensive firms. On the other hand, the role of universities in spurring regional diversification should be specifically tackled, in line with the evidence gathered here.

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