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Extended abtract

EXTENDED ABSTRACT

Title:
Specialization, diversification and environmental technology life-cycle

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Abstract:

Prior literature has long since acknowledged that innovation depends on the ability to accumulate and recombine existing knowledge (Aghion and Howitt, 1992; Jones, 1995; Weitzman, 1998). A key question is whether any such combination is equally successful or if, instead, particular characteristics of knowledge matter more than others for generating innovation. According to a recent approach in economic geography, two complementary pathways can spur innovation in a regional economy. One dates back to Marshall's (1920) idea of interaction and proximity of goals and of competences. The other stems out the work of Jane Jacobs (1969) and thrives on the diversity of competences of the local economy. Importantly, the two are not mutually exclusive: empirical evidence suggests that, depending on the particular circumstances at hand, both pathways can play an important role (Glaeser et al., 1992). Frenken et al. (2007) elaborate a synthesis of these ideas building on the distinction between related variety – i.e. within-industry diversity due to connection of activities that share similar resource bases – and unrelated variety – between-industry diversity that thrives on spanning a wide spectrum of different, possibly not connected, capabilities (Boschma et al., 2009; Boschma and Frenken, 2011). A recent study by Castaldi et al (2015) further enriches the debate by showing that related variety and unrelated variety are distinct but

connected dimensions in the multi-stage innovation gradient. In particular, related variety concerns innovations that develop incrementally out of established cognitive structures across connected domains while unrelated variety, though more uncertain and initially costly, can be a catalyst for breakthroughs that span, by necessity or by design, new functionalities. Cogently, the former stems out of the other. Indeed Castaldi et al (2015) conclude that unrelated variety paves the way to frontier technologies that will become more related as they mature and stabilize.

The present paper adopts the outlined conceptual framework to elaborate an empirical analysis of environmental innovation capacity in the United States (US). The field of green technology (GT) encompasses a continuously evolving group of techniques and practices aimed at reducing pollution or containing environmental impacts. The complex nature of environmental problems entails that the spectrum of necessary technologies is broad, meaning both that they draw on various domains of human know-how but, also, that their effects impinge upon different realms of human activity. Moreover, responding to environmental problems plays out over long time horizons and, thus, in parallel to the evolution of interrelated fields of expertise that can augment or hamper the effectiveness of novel technology. Last but not least, GT is an uncertain endeavour because the expected returns are likely to be uneven in terms of both economic and environmental outcomes. This and other forms of uncertainty are problematic for the design and implementation of environmental policy because they make technology evolve in unexpected ways, or at an unexpected pace.

In spite of said complexity GT is commonly, but in our opinion erroneously, referred to as a generic set of techniques. This misrepresentation is a serious shortcoming both for scholarly and policy purposes. The present study seeks to tackle this issue by detailing the evolution of different families of green technologies in the US. Our goal is threefold. First, we seek to map the distribution of patenting activities pertaining to environmental technology across US states between 1980 and 2010. To the best of our knowledge no one has so far thoroughly described the “what, where and when” of green invention. Second, we aim at identifying the stage of development of green technologies employing the life-cycle heuristic to study the role of the regional knowledge base. On the one hand, this will enable a comprehensive mapping of green technologies based on their stage of development that the related literature, so far, has neglected. On the other hand, identifying the socio-economic premises that contribute most to the evolution of green technologies at regional level affords the opportunity to offer straightforward policy implications. Third, coherent with Castaldi et al (2015), we set out to provide direct evidence of the relationship between regional economic variety and invention capacity against the backdrop of a rapidly evolving technological paradigm. This promises to be an addition to ongoing debates in both environmental economics and economic geography.

The main data source is the database PATSTAT (version 2016a) and the ENV-TECH patent search strategies developed by OECD (2016 version). Our method consists in parsing ENV-TECH to identify GT domains through all the IPC/CPC codes and intervals that fall in each category (at 2- and 3-digit level), convert IPC codes into CPC codes and explore the CPC classification to obtain all the children codes.[1] Once the code list has been generated, we identify in PATSTAT all the patent applications with at least one of them. We then obtain, for each patent family, its earliest priority year, its cpc classes (full symbol), its ENV-TECH class and the inventors' addresses. Finally, to identify US States from an address, we geolocalize at city level using information from Geonames database (in particular postal codes, official and alternate city names) and a geolocalisation API. Once we have the coordinates of the city where the address is located, we project these locations to the states map.

Our methodology aims at assessing whether variety in the regional knowledge base and industrial structure affect the green innovative activities in US states. In addition, we seek to test whether and to what extent the life-cycle stage of green technologies affect the relationship between knowledge diversification and innovative activites. This entails two methodological challenges. First, we need to measure diversification and, second, to identify the stage of technology life-cycle. As regards the former, we calculate diversification based on entropy (Jacquemin and Berry, 1979; Attaran, 1986). This measure can be decomposed at different digit levels of the hierarchical structure of the data (Frenken et al., 2007) and takes into account both absolute and relative abundance of groups in this structure (Wixe and Andersson, 2017).

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[1] For example, the ENV-TECH search strategy "6.3. Air Transport" is associated with the CPC code Y02T50. We explore the CPC classification to find the children of this code and we obtain all the codes between Y02T50-00 and Y02T50-90. Additionally, for the first two categories (Environmental Management and Water Pollution Abatement), a previous step is to convert the IPC classes to their CPC equivalent using the CPC Concordance table published by EPO and USPTO.

We measure related and unrelated variety using employment data at the state level (Frenken et al., 2007). In addition, we calculate related and unrelated variety to capture within and between diversity across technological fields (Castaldi et al., 2014) using the count of patents at three and five digits of the Cooperative Patent Classificiation (CPC). These variables differ from previous ones in that they capture knowledge spillovers across technological fields rather than across industries. It has been acknowledged that the variety of the knowledge base at the technology level affects the propensity to engage in innovative activities (Castaldi et al. 2014). In addition, it enables us to test whether the evolution of green technologies moderates the relationship between the exploitation of a variety of (related and unrelated) technological domains and innovative activities.

The second building block of our methodological framework targets the identification of technology life-cycle stages. So far different attempts have been carried out to track TLC stages (Haupt et al., 2007; Gao et al., 2013; Chang and Fan, 2016; Lee et al., 2012; 2016). Since a standard practice has not yet been identified in the related literature, our aim is to build a composite index that measures technology life-cycle stages that meets a number of requirements, namely: it accounts for the idiosyncratic features of each GT; it is usable in an econometric model; it exhibits substantial variation across green technologies; it can be extended to a wide range of technology studies.

Summing up, we expect this empirical analysis to address a number of policy relevant questions, such as:

- What is the current stage of development of each of the eight domains of GT?
- Which US geographical areas are leading in each domain of GT? When did their technological advantage consolidate?
- What explains the correlation between leadership status of an area and the particular life-cycle stage of the dominant GT in that area?
- Do technologies at early (late) stages of the life-cycle exhibit higher levels of Unrelated (Related) Variety?

Our preliminary results suggest that unrelated diversification in the regional knowledge base is associated with an increase of green innovative activities. However, this holds only in richer regions, whereas in lagging ones the main driver of green innovation is

diversification across cognitively related technological fields. Different patterns are observe when comparing green and non-green regional innovative efforts. Finally, we found that regional environmental-related innovative activities benefit from unrelated diversification of the knowledge base in the early stages of technology life cycle. Contrarily, in the maturity stage green technologies are correlated with a regional knowledge structure diversified across related technological domains.

Keywords: green technologies; technology life cycle; knowledge diversification
JEL codes: O31, O33