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Technological relatedness and industrial transformation:

Introduction to the Special Issue

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Abstract
This article introduces eleven research articles that connect concepts of technological relatedness and diffusion with the transformation of industrial and innovation systems. These studies focus on the role of knowledge spillovers, regional variations in innovation and performance, and the evolution of new technologies, such as green and digital technologies. Regional capabilities and ability to diversify are key in accelerating the transformation process of existing industries

Taken all together, these studies suggest that industrial transformation hinge on firms capability to absorb domestic or foreign knowledge, regions capabilities, development trajectories, and their ability to network. In particular, regions capacity to diversify and leverage existing related knowledge are key in accelerating the green and digital transformation process of existing industries.

Keywords technological spillovers · industrial specialization · industrial diversification · new technologies · industrial innovation

1 Introduction

Research in evolutionary economics has extensively explored the role that innovation (Dosi & Nelson, 2010; Coad et al., 2019) and technological relatedness (Boschma & Frenken, 2011; Hidalgo et al., 2018) play in the evolution of activities of firms, cities, regions, countries, industries, and global innovation networks. These strands of research have found that

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the interactions between technologically related activities can lead to new technologies (Boschma et al., 2015), innovation in science (Pugliese et al., 2019), and even entirely new industries (Neffke et al., 2011). However, there can be barriers in the form of intellectual property rights which inhibit collaboration and technology transfer among firms (Hall et al., 2001; Hall, 2014). We know relatively little about the interplay between the technological relatedness and diffusion and the transformation of existing industries. To provide an example, the automotive industry is currently undergoing a radical transformation, as the future of mobility is increasingly complex (more electrified, autonomous, shared, and connected) and will require the integration of related and unrelated technologies as its business models evolve (Stolfa et al., 2019).

Sweeping transformations driven by new technological trajectories such as fragmentation of production (Antras, 2019), changes in dominant technological systems (Murmann & Frenken, 2006), automation (Brynjolfsson et al., 2018), artificial intelligence (Dernis et al., 2019) or new technology-based business models (Jamil et al., 2019) are affecting several industries and socio-economic systems. Therefore, it becomes more important than ever to understand how firms, cities, regions, and countries can evolve and adapt. Industrial and innovation policies are also expected to evolve to deal with such transformation (Dosso et al., 2018). As a handful of studies, particular on skills, have begun to show (Alabdulkareem et al., 2018; Nedelkoska et al., 2018), technological relatedness can offer a key to look at these questions.

This special issue presents research that connects concepts of technological relatedness and diffusion with the changes in industrial and innovation systems. The eleven papers in the special issue divide into roughly three areas: (1) the role and degree of knowledge spillovers at the local and international levels; (2) variations in innovation and performance across regions and policies that affect these; (3) evolution of new technologies, especially green and digital technologies, with a focus on opportunities for adoption by regions and countries. Together these papers enhance our understanding of the evolution of various technologies and sectors at the regional and national level and how to influence it.

2 Knowledge spillovers

Knowledge spillovers transform industries from within the region, as new knowledge and technologies created in local firms spill over to other industries and regions (Li & Bosworth, 2020). The effect of this change depends on sharing complementary technological experiences and knowledge bases between firms and organizations (Boschma & Frenken, 2009). Guerrero et al. (2022), using Spanish firm-level data, show that the heterogeneous effects of knowledge spillovers on firms' growth depend on the joint role played by firms' absorptive capacity and the use of external sources of knowledge. Firms with relatively high absorptive capacity grow more from upstream spillovers compared to firms with relatively low absorptive capacity. At the same time, horizontal spillovers seem to have a positive effect on growth when firms rely on domestic or foreign knowledge sourcing.

Attracting foreign know-how and capital is often regarded as an important channel for knowledge spillovers, as foreign firms could transfer new capabilities, skills and technology to domestic firms, as well as favour their integration into global value chains and access to new markets, thereby widening regions' capability bases and increasing their diversification

opportunities. Spithoven & Merlevede (2022) study the productivity effects of R&D or FDI spillovers on Belgian firms and find that the impact of spillovers and their contribution to industrial transformation differs according to the regional development path. The authors characterise this path using the varying degrees of organisational thickness and specialisation of the regional innovation system.[1]

Landman et al. (2022) study the impact of MNEs on the dynamics of domestic industries in Irish regions. More specifically, they look at whether the presence of MNEs in a region results in knowledge spillovers and the creation of new domestic industries in related sectors. Overall, new domestic industries are more likely to enter and survive in Irish regions if they are related to industries that are populated by both domestic firms and MNEs. Conversely, they are less likely to enter and survive if related to an industry dominated by MNEs, as the technology gap is too wide for domestic firms to be able to absorb foreign knowledge and catch up. Taken all together, these studies indicate that the impact of spillovers and their contribution to industrial transformation hinge on firms' capability to absorb domestic or foreign knowledge, and the development and specialization of regional innovation systems.

3 Regional technological capabilities variation

Differences in innovation capacity, economic performance, and policies across regions can affect technological relatedness and technology diffusion, and their impact on the transformation of existing industries (Corradini et al., 2021). According to Whittle & Kogler (2020) the relatedness between different products, technologies and industries ('related variety', Franken et al., 2007) affects the scale and scope of future regional diversification, although economic agents that differ in their expertise are more likely to diversify into those areas that are cognitively proximate to their existing specialization.

The two underlying questions are: What is the role of innovation and technological relatedness for industrial transformation? And how should industrial and innovation policies evolve to deal with such industrial transformation? This section of the special issue presents papers that look at these questions at the regional level.

The role that innovation and technological relatedness play in the evolution of industries and the role of cluster policies are at the basis of a successful industrial transformation, and technical change is driving force behind industrial transformation (Freeman and Louçã, 2001). Both technical change and industrial transformation are dependent on regional technological strategies and related supportive policy measures, which differ from region to region (Spithoven & Merlevede, 2022).

The Basilico et al. (2022) study focuses on the German "BioRegio contest", a programme that aimed to identify and strengthen clusters that were already performing well in biotechnology. The study looks at whether the "BioRegio contest" programme affected the knowledge space evolution of the selected region. They find that biotechnology patent classes become more embedded in the regional knowledge space (increasing its knowledge), after

[1] Organisational thickness refers to the presence of many firms in various industries, a critical mass of higher education institutes and research centres, and public support structures that stimulate innovative activities in promising technological domains (Boschma, 2015; Binz et al., 2016).

the introduction of cluster policy measures. These findings imply that a cluster policy can reshape the technological space of the funded regions.

Important factors for innovation and industrial transformation are the knowledge and the skills along with the economic structure of a given economy (Whittle & Kogler, 2020). Fagerberg and Srholec (2022) use 261 regions in 27 European countries to examine the roles of capability building and diversification in regional economic development, finding that capability building (both technological and social) dominates.

Within the same context, the literature analysing how the network properties of regional knowledge spaces contribute to technological change within the region is scant. Kogler et al. (2022) study this topic using regional data for15 EU countries. They find that a region's ability to venture into high-potential areas of technological specialization in the knowledge space outperforms purely relatedness-driven diversification.

The transformation of existing industries though innovation and technological relatedness relies very much on the knowledge transfer, not only across firms within a given region, but also across regions. Miguelez and Morrison (2022) examine the role of migrant inventors in transferring knowledge between regions, finding they are important in developing new technological capabilities in the destination country by bringing knowledge from their origin country.

Overall, these original contributions add to the literature by suggesting that industrial transformation can be achieved through innovation, technological relatedness and diffusion across economic actors and territories. The region's own capability to build capacity and ability to diversify is key and tailored 'transformative' industrial and innovation policies could accelerate the transformation process of existing industries.

4 New technologies

An extensive literature has documented that technological relatedness contributes to the structural change of the economy (Hidalgo et al., 2018). This process of transformation is, in fact, rather disruptive, and it is often only thanks to a gradual movement from existing knowledge to related new knowledge that a firm, a region, or a country can master new technologies and dominate new industries.

However, the emerging technological trajectories of the 21st century are forcing our techno-socio-economic systems to adapt quickly – in particular, converting our economy to climate neutrality and adapting to fast growing digital technologies – and are leading us to revisit the role of relatedness under a new light. While relatedness research has typically focused on which country could become a leader in which technology, these generational changes are going to affect most industries everywhere. It is no longer a matter of who could do what, as no one (no industry, no country) is granted the luxury of choosing not to participate in this massive techno-economic reorganization.

To facilitate the shift, it becomes paramount to understand what factors influence the adoption of these new technologies and what role already-existing related know-how has to play. A number of papers in this special issue took up this challenge, by studying – although with different methods – the diffusion and adoption of some of these transformative technologies.

Santarelli et al. (2022) focus on Artificial Intelligence and Robotics. The authors note that their transversal application makes them General Purpose Technologies. If one considers these two technologies jointly – which, according to their analysis, one could to a large extent – they can be viewed as constituting a new techno-economic paradigm. By matching patents to firms, Santarelli et al. (2022) also show the degree of pervasiveness of these technologies: they are found in a relatively broad spectrum of sectors, as well as across many countries. Notwithstanding their considerable diffusion, the United States emerges as the clear leader in these technologies (although some Asian countries are closing the gap). Moreover, some industries, such as computer and manufacturing, are clear leaders in the patent production of these technologies, which means that it may be to the advantage of the countries specialised in these industries.

Li et al. (2022) study two important green energy-generation technologies: photovoltaic and wind power. Measuring breakthrough innovation as the first appearance of a pair of technology codes (IPC) in a patent, the paper analyses how long it takes to another country to adopt that innovation, regressing this lag against an array of potential factors. They confirm the importance of the domestic knowledge base by looking at the country strength in the constituent IPC codes in the new combination. However, they found that multinational inventor network effects are also very important, highlighting the role of multinational firms in helping the circulation of know-how across country boundaries.

Another paper that finds a prominent role for networks is Costantini el al. (2022). Focusing in this case on energy efficiency technologies, they employ spatial econometric techniques to uncover an important role for trade networks in the diffusion of these technologies. These authors further show that the likely mechanism behind these spillovers is learning by exporting. Unfortunately for regions which are lagging in these technologies, this paper too observes that the benefits of the trade network depend on the absorptive capacity of the receiving country, measured as specialisation in Key Enabling Technologies.

Finally, Barbieri et al. (2022) look at green technologies in a more holistic manner. The paper – keeping its focus on endogenous transformation – maps how green technologies are related to non-green technologies, thus drawing pathways for countries to move from their knowledge base to the new paradigm. The paper however notes that only very few regions in Europe have the local capacity to patent at the highest level in all green technologies.

Taken all together, these contributions suggest that the transition to green and digital technologies seems inevitable and will involve many industries at once. It will be key to a smooth transition to leverage existing related knowledge, but this will not always be available locally. Tapping into the network may help reducing the gap of lagging regions, although additional measures may be required to compensate for the low absorptive capacity we observe in lagging regions.

5 Conclusions

Major industrial transitions in energy and transport systems, new green and digital technologies and historical shifts in social and demographic patterns are driving the socio-economic transformation of industries and territories. Clearly this transformation comes with its challenges and opportunities for firms and government policy. The findings of the articles in this special issue have several important implications for policy.

The first implication is the importance of the local knowledge base and capabilities for future development. These are vital not only to enable firms to adopt new technologies and to absorb foreign know-how successfully, but also for regions to evolve and update their industrial composition, and to venture into new areas of technological specialization.

The second is the importance of networks and knowledge transfer. The EU depends on access to critical technologies from other countries and needs to improve its capabilities in order to identify R&D investment gaps and to hone in on the appropriate selection of technologies relevant to achieving sustainable competitiveness and socio-economic prosperity. In addition, within the EU, there is wide variation in the local knowledge base, suggesting the importance of networks and knowledge transfer at that level as well as outside its borders.

Taken together, these two implications suggest two more specific recommendations. The important role played by regional capabilities in several of the papers suggests that attention be paid both to local educational opportunities and to cross border study, especially given the importance of migrant inventors. There may also be a role here for exploring best practices across countries in ensuring that entrepreneurs and inventors find starting a new company in a particular location attractive.

Related to this, it is important to facilitate the cross-border movement of skilled personnel, scientists, engineers, and entrepreneurs by reducing the transactions and other costs associated with such moves. Such policies might include things like ensuring pension portability for those workers who are not employees of large multinationals.

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