Regional patterns of 4.0 technological transformations: conceptual reflections and empirical evidence from European regions

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1. Introduction and aim of the paper

The creation and adoption of the new 4.0 technologies such as artificial intelligence, intelligent robotics, analytics, just to name a few, are expected to drive pervasive transformations and, potentially, radical impacts on the economy and the society (Schawb, 2017; Brynjolfsson and McAfee, 2014, 2017; Ruallni and Rullani, 2018). These transformations affect phenomena as diverse as the opening of market opportunities to newcomers in the technology market, and to user innovators, the creation of new digital services (Servitisation), the automation of industrial production processes (Industry 4.0), new service delivery and new traditional industry activities (digitalisation and robotisation of traditional activities). In short, changes are deemed to affect all industrial production processes, the creation and delivery of new services, but also traditional activities that switch to digital business models.

The impact of these transformations is expected to be large. However, the territorial dimension of these phenomena has been largely neglected in the literature so far even if empirical evidence is expanding in the very last years (De Propris and Bailey, 2020; Barzotto et al., 2019). Yet, there is urgent need of deeper knowledge and understanding of how and through which channels the present technological transformation is taking place in regions creating and adopting the new technologies and how regions can grasp the opportunities opened by the new technologies and minimize the social frictions in the labour markets and the widening social inequalities**.**

This paper aims at filling this gap from both a conceptual and an empirical perspective with the aim to identify a taxonomy of European regions based on the prevailing technological transformation, taking place in each regional economy.

2. Conceptual approach

On conceptual grounds, the paper offers an original comprehensive and systematic picture of 4.0 technological transformations and of their intertwined regional / sectoral effects,

which is still missing in the literature. In particular, the paper separates out conditions for, characteristics of, main actors/sectors involved, positive and negative spatial economic effects of the technological transformation, taking place in in industrial production processes and in the society because of the use of new, improved, differentiated or digitalised services.

These technological transformations are conceived as a *sector-driven phenomenon*, based on the awareness that sectors differ in terms of the inputs and technologies used as well as of the production structure, and, therefore, in terms of the profitability gains that technology adoption can generate (Malerba, 2002). Accordingly, the paper posits that regional economies are affected by the present technological transformations depending on their sectoral specialisation and technology adoption intensity in the sectors mostly involved in the new technology production and adoption. In this respect, sectors can be classified in three main groups:

- *technology sectors*, representing those sectors where the new 4.0 technologies are mainly produced. Their market size depends on the rhythm of penetration of the new technology;
- *carrier sectors*, representing those sectors where the new 4.0 technologies are adopted, and partly also co-invented and/or produced;
- *induced sectors*, representing those sectors that, because of their production structure, exploit the advantages of the technological change as a consequence of and complementary to the growth of the carrier Nonetheless, technological change can improve productivity also in these sectors.

Regions characterised by the highest specialisation in technology and carrier sectors and with the highest intensity of adoption in these sectors are expected to be subject to the deepest changes.

1. Empirics

On empirical grounds, the paper documents the existence of multiple and concomitant transformations in European NUTS-2 regions by combining multiple sources of data. Regional sectoral specialisation in the three groups of sectors within manufacturing and service sectors is analysed on the base of EUROSTAT Structural Business Statistics, which provides regional employment data disaggregated at 2-digit sectoral level of the NACE Rev. 2.2 classification, for the period 2008-2016. Regional sectoral adoption in the three groups of sectors within manufacturing and service sectors is analysed on the base of the degree of diffusion of automation technologies (i.e. robot density) and the degree of digitalisation of services (i.e. pervasiveness of online sales). Data on regional robot adoption intensity is sourced from the International Federation of Robotics (IFR) at the sectoral national level, next apportioned at the regional level. Data on regional intensity of online sales is sourced

from EUROSTAT at the sectoral national level, next apportioned at the regional level.

A k-means cluster analysis on six regional sectoral specialisation variables (i.e. specialisation in technology sectors, specialisation in carrier sectors, specialisation in induced sectors, distinguishing between services and manufacturing) has been used to group European regions according to their predominant technological transformation and five groups of regions have been identified.

Various statistical criteria have been considered to identify the appropriate number of clusters to be retained, such as the relationship between within-cluster and between-cluster variance, but also the number of regions per se. The balance between the information advantages provided by expanding the number of clusters and the interpretability of the results in terms of technological transformation patterns supported the extraction of five clusters; each cluster included a reasonable portion of observations, so that they could be plausibly interpreted as *regional patterns of 4.0 technological transformation*. They statistically and significantly differed in the main variables used for the clustering exercise, as the results of the ANOVA tests presented below show. Indeed, the magnitude of the F values performed on each dimension is an indication of how well the respective dimension discriminated between clusters. These five clusters were overall highly stable. Repeating the extraction with different similarity measures and specifying different k random initial group centres yielded highly consistent results. In fact, only a minor portion of regions was assigned to a different group.

2. Main results

Performing an ANOVA exercise on a series of variables describing the regional degree of 4.0 technologies adoption, regional structural characteristics and enabling condition for adoption (e.g. education, entrepreneurship) provides interesting additional information that made it possible to emphasize and to interpret the profile of the different groups of regions in terms of key distinctive territorial preconditions for technological transformation.

Each of the five clusters can be associated to a prevailing technological transformation, as follows:

- **Servitisation** prevails in regions characterised by the presence of high specialisation and high adoption in technology and carrier services. This transformation takes place in a few number of regions, especially large city regions, characterised by a high penetration of digitalisation in service and a high entrepreneurial This last feature highlights the creative ability in exploiting such new technologies for new business models.
- **Industry 0** characterises those regions with a high specialisation in technology and

carrier manufacturing sectors and with a high adoption of industrial robots. These regions are in a few number, located mainly in Southern Germany and Northern Italy

- **Digitalisation of traditional service** is predominant in regions with a high specialisation in induced service sectors and by a relatively contained adoption of 4.0 technologies. The digitalisation in the service sector is the most populated among the five These regions are mainly Southern Italy regions, some regions in Spain, parts of the UK (with the exception of London and its surroundings), Baltic regions, regions in Norway, Northern Germany, and part of the Netherlands.
- **Robotisation of traditional manufacturing** occurs in regions with a high specialisation in induced industry sectors and a relatively contained adoption of 4.0 technologies. Most regions in Europe, especially in France, Poland, Central Italy, and Hungary register the adoption of robots in induced
- **Niches of robotisation** prevail in regions in which technological transformation takes place only in small industrial niches, but does not pervade completely the regional economy. These regions are located mainly in Eastern countries, Greece, part of Spain and a few regions in These regions show a very low adoption, and a specialisation in industrial sectors which are however very small sectors. These areas are characterised by a very high risk of job automation.

3. Conclusions

The results highlight the large heterogeneity of transformation processes across European regions and how only few of them are involved in the most radical transformation paths (i.e. Servitisation and Industry 4.0). Many regions still have limited transformation, either because transformation affects large but less dynamic sectors or because transformation hits only few industrial niches.

Importantly, these results stress that much of the 4.0 technological transformation and penetration depends on the sectoral specialisation of the region. In fact, each sector is influenced by a particular technological transformation, by making use of and get advantages from specific 4.0 technologies. Policies necessarily have to be tailored to the technological transformation present in the region, in line with the premises and guidelines of the Smart Specialisation Strategy.

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