Industry 4.0 Technologies and Italian Urban System: Between Smart Development and Increasing Inequalities

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Abstract. The growing diffusion of new digital technologies are leading to profound changes and disruptions in various areas of human life (personal, social, economic, environmental, …). The scale and intensity of these changes call for an analysis of their impact both towards development opportunities, and negative effects related to potential spatial inequalities. The aim of this paper is to understand how much the 4.0 technologies (IoT, 5G, sensors, robotics, AI, Big Data, etc.) have penetrated the Italian urban system, and whether this technological enhancement involves a widespread improvement in general conditions or, on the contrary, precedes an increase in the gap between smart cities and struggling cities. In addition to undoubted advantages coming from big data availability for waste management, air pollution control, energy efficiency, mobility management and overall urban planning, it is important to assess economic, social and territorial disparities, as possible effect of incorrect planning, lack of investments, inadequate policies and/or linked to specific geographic characteristics and different urban visions. After an initial theoretical framework on the Italian urban system, characterized by a high number of small and medium-sized cities with different responses to smart policies, the paper focusses on the distribution of 4.0 technology patents acquired in Italy between 2016 and 2021, considered at a NUTS 3 level. This methodology allows on the one hand to consider how responsive cities are and on the other to compare this response with general KPIs of the urban contexts.

Keywords: Industry 4.0 technologies · Smart development · Patents · Italian urban systems · Territorial disparities

1 Introduction

This paper intends to present the main goals, methodology and first results of a wider research project, aimed at representing the impact of the fourth industrial revolution, through historical-economic, historical-political, socio-cultural and geographic approaches. The dynamics of Industry 4.0 have so far been studied mainly by technological disciplines, which deal with developing enabling technologies and extending their

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application, and the economic ones, which analyze the effects on regional and industrial competitiveness, on productivity, work organization [1]. However, the complexity of the phenomenon and the extent of its impact, also from a social and cultural point of view, recalls the need of the contribution of various disciplines and systemic interpretations to understand the connections between different spheres and outline future scenarios. In this context, the geographic approach can contribute because it helps to observe the territorial contexts where technologies develop, the concentration and diffusion processes, the places where they arrive or do not. In this sense, technologies are powerful agents for territorial transformation and for the generation of new spatialities and multiscalar connections.

This paper focuses on the geographical perspective, showing some initial reflections and results about the impact of Industry 4.0 technologies on the dynamics of smartness in the Italian urban system. In particular, the empirical work analyses the spatial distribution of 4.0 technology patents obtained by Italian inventors between 2016 and 2021, considered at a NUTS 3 level. The results show the asymmetry among different areas in Italy and also among systems characterized by large cities and others where small and medium-sized ones are present. This comparative analysis also allows to outline a new picture of the geographies of inequalities linked to Industry 4.0 technologies and to reflect on the policies connected to them, which should consider different response capacities of territorial contexts to smart paradigm and to current technological paths.

2 Theoretical Framework

The relevance of changes that have taken place in production systems and spaces, in the way the job market is organized, in the qualification of human resources [2, 3], as a consequence of the diffusion of the advanced latest technologies (robotics, 3D technologies, Artificial Intelligence, IoT, IoE, LBS, etc.), tends to justify the use of expressions such as the fourth industrial revolution. What distinguishes this revolution from the previous one is the speed with which technological changes take place, the extent and intensity of connections and transformations, the impact it is determining both in production processes and in work 4.0 [4, 5].

The complexity and pervasiveness of the changes that Industry 4.0 technologies are determining on the economic and productive system on the one hand and on social dynamics on the other, oblige to focus attention on what the impact of these changes can be both in positive terms, such as development opportunities, and in negative terms, such as the amplification of social inequalities or marginalization phenomena at different territorial scales [6].

From a geographical point of view, the focus is on how territorial systems and cities are strengthened and at the same time transformed by new technologies, both in terms of forms and landscapes and in terms of economic, social and cultural components. Internet networks, investments in sensors and 5G technologies, robotics, online platforms, are all technologies that are changing not only production spaces and, more generally, cities, making them increasingly smart and more connected systems in which physical and digital spaces, individuals and networks, multiple flows and identities intertwine.

Although the advantages of their diffusion are clear, Industry 4.0 technologies and their applications in cities, however, may increase not only social gaps but also disparities

at different territorial scales: for example between advanced and emerging countries, or between metropolitan and peripheral ones, or among the different parts of cities [7]. The problem of technological and territorial gaps represents an important issue in the scientific and political debate; therefore, it appears important for understanding if Industry 4.0 may activate diffused smart development among regions or, on the contrary, contribute to a persistent divide between technology leaders and laggards [8].

Since it is assumed that the "smartness" degree of a territory is expressed by the improvement of the quality of life of its inhabitants, it will be important to analyse what its response is at the introduction of these technologies and whether they play a role in increasing social inequalities or, on the contrary, in the reduction of the pre-existing gaps, with evident repercussions in the political and territorial governance choices [9]. In this regard, the recent literature on innovation studies argues the need to rethink policies finalised to reduce inequalities and improve the different types of regions, through the promotion of place-sensitive development logics and the integration of various actions [10]. The objective is to intervene on standard contextual factors (education, employment, infrastructures, etc.), but also on the absorptive capacity of technologies by local systems and on specific innovative potentials, in terms of digital connectivity, technological competences, combination between advanced technologies and manufacturing sectors.

3 Main Goals and Methodological Approach

The reflections presented in this paper are part of a wider research, aimed at representing the impact of the fourth industrial revolution through the analysis of empirical evidence and the use of key performance indicators, according to differentiated theoretical and methodological perspectives. These representations will contribute to the identification of increasing opportunities, linked to the Industry 4.0 paradigm, and emerging divergences in the world of work, in society and in the territories. In particular, the main goal is to emphasize the geographical perspective, presenting some initial methodological reflections on the impact of Industry 4.0 technologies in the dynamics of "smartness" concerning the Italian urban system, with particular regard to the different answers of cities and to the formation of disparities between areas of the country and between cities of various sizes.

From a methodological point of view, in other works we have elaborated some data (source ISTAT) regarding technological investments, innovative projects and interventions on digital skills carried out or planned for the future [11]. Figure 1 represents the comparison among the 14 Italian metropolitan cities, both in terms of the number of enterprises investing in projects of innovation and in the second map related to the category of investments in digital and technological sectors. Analysing the first map, it is possible to highlight three distinct groups: a) with the highest values, we can group the areas of Milan, Rome and Turin; b) Naples, Florence, Bologna, Bari and Venice belong to a second group with intermediate values; c) the remaining metropolitan cities, Genoa, Palermo, Catania, Messina, Cagliari and Reggio di Calabria have the lowest values of digital investments.

The map on the right represents the total number of investments made, classified by different types of investment. It shows a strong propensity towards infrastructure (optic

fiber and 4-5G connectivity in all cases hold the majority share of the investment), which is at the same time an indication of a primary need of firms and also of a gap in terms of the digital accessibility.

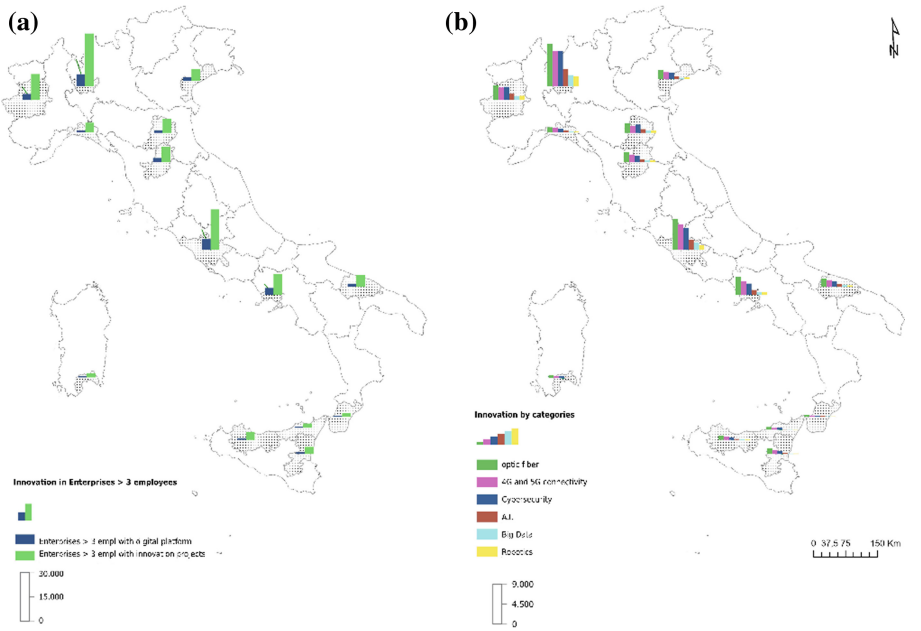

Fig. 1. A) Enterprises investing in projects of innovation, and B) categories of investments in digital sector, grouped by metropolitan cities. Source: ISTAT

Considering some European studies on a regional scale (NUT-2) [8, 12], in this paper we have tried to reflect on the geographical distribution of Industry 4.0 technologies, exploring the number of the European Patent Office (EPO) patent applications across NUT-3 areas in Italy between 2016–2021. Patent data has long been used in the literature and at European level to analyse innovative performance of regions and their capacity to produce and apply technologies. In this work we focus our attention on patents related to Industry 4.0 technologies, considering both the EPO classification (2017; 2020) [13] and a more restricted selection of Cooperative Patent Classification (CPC) classes, which is elaborated using specific keywords according to a methodology proposed by other recent studies [14]. Patents are allocated to NUT-3 Italian provinces considering the inventor's location and technological class of the patent.

This methodology of analysis based on patents in 4.0 technologies allows us to add a further step in the understanding of spatial patterns in the creation and diffusion of smart technologies and of the geography of the Fourth Industrial Revolution.

4 Results

As a general statement, the Italian urban system is characterized by a high distribution of small and medium-sized centers compared to a small number of large cities. According to previous studies [15], the asymmetry of metropolitan areas emerges in Italy: Rome, Milan and Naples, for example, have critical housing densities, with all the problems that arise, and a significant gap is highlighted between the metropolitan cities of the center-north and the south of the peninsula in terms of some smart components.

The area of origin of the patents (Fig. 2, Fig. 3, and Fig. 4) is aligned with a general picture of division between North and South and confirms some results emerged from the distribution of investments in innovation projects and digital sector (Fig. 1).

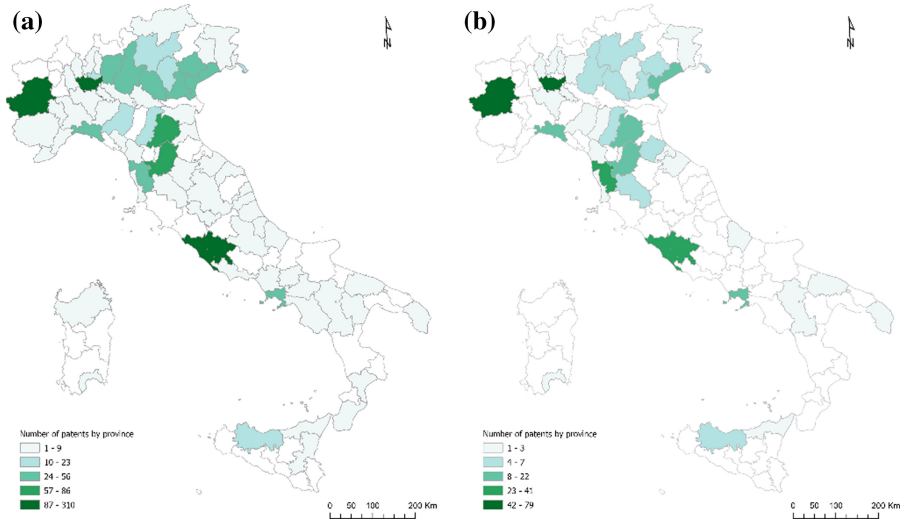

Fig. 2. Italian patents related to Industry 4.0 technologies issued between 2016–2021: A) according to EPO classification, and B) according to CPC restricted selection (Martinelli *et al.*, 2021). Source: Data of the European Patent Office, elaboration by the authors.

As can be seen, the classification proposed by EPO includes a greater number of patents (just under 400) with a marked concentration in the central and northern provinces, with the slight exceptions of Naples and Palermo (in ninth and twenty-first place, see Fig. 3). Milano, Torino and Roma are attested with significantly higher values compared to the other provincial averages; these data confirms the relevance of these three areas in the ability to produce new technologies, in connection with their economic development, the concentration of universities and research centers and qualified human resources, the demand for innovation of the local ecosystem. The provinces included in Lombardia, Veneto, Emilia Romagna regions, which are the most industrialized areas of the country and present a tradition in small and medium-sized manufacturing, have a more homogeneous and continuous distribution. As can be seen from Fig. 3, other Italian metropolitan areas emerge, such as Bologna, Florence and Genoa, but also provinces with

smaller cities oriented towards Industry 4.0, thanks to the push of the university research activity (such as Pisa, Padua or Trento) or of a manufacturing context more oriented towards technological changes (such as Bergamo, Brescia, Treviso, Parma). Despite the phenomenon of territorial polarization, the EPO classification reveals a widespread presence of patent production in Italy, which however excludes the provinces that are geographically more marginal or specialized in other activities such as agriculture and tourism.

The second classification, which is more restrictive, considers a number of patents equal to approximately one quarter of the previous one. As can be seen from the map, the distribution is spatially more selective and strongly unequal between areas of the center/north and south. This classification strengthens metropolitan areas and those that rely on a high-level university or specialized in scientific-technological disciplines. A university city like Pisa (Fig. 4) emerges from the previous picture, a sign that the presence of higher education institutes in the area also impacts in the production of new technologies.

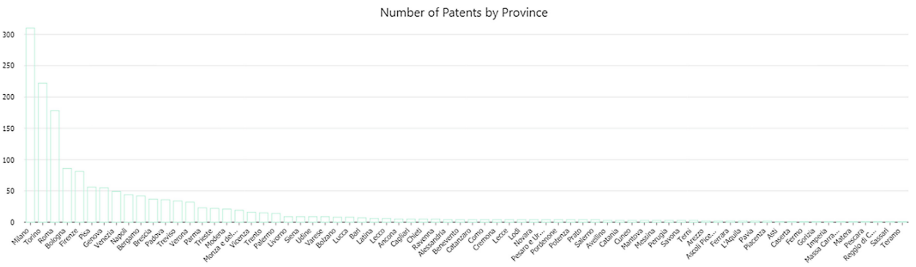

Fig. 3. Italian patents related to Industry 4.0 technologies issued between 2016–2021 according to EPO classification. Source: Data of the European Patent Office, elaboration by the authors.

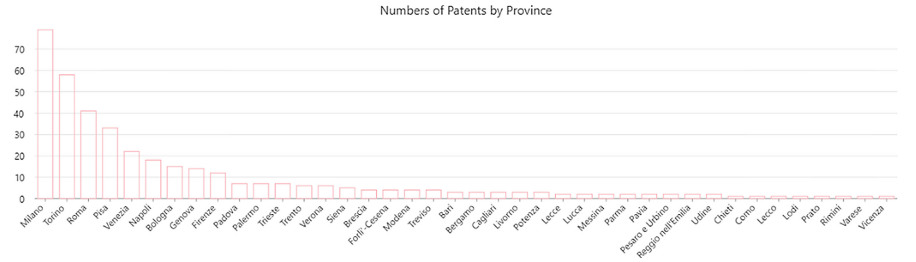

Fig. 4. Italian patents related to Industry 4.0 technologies issued between 2016–2021 according to CPC restricted selection (Martinelli *et al.*, 2021). Source: Data of the European Patent Office, elaboration by the authors.

In fact, all the provinces characterized by a marginality linked to the predominantly mountainous territorial configuration and/or in an internal area position are excluded from the innovation processes that go through patents. The picture that emerges from Fig. 2B is definitely alarming: large areas of the southern center and islands are not

affected by the phenomenon. The only exception is Naples, which is confirmed to be a growing area for which the outcomes of recent years investment policies and the creation of technological districts emerge.

5 Conclusions

The comparative analysis of the impact of the growing diffusion of Industry 4.0 technologies and smart dynamics in the Italian urban system allows us not only to outline a picture of the differences, but also to reflect on the policies connected to them, which often have replicated initiatives without considering the different territorial characteristics and the different response capacities of urban contexts.

The analysis proposed here required the extraction of patents attributable to Industry 4.0 from the dataset of the European Patent Office, according to two different classifications. The results, although differing in quantity and quality of the data, converge in outlining a strong gap between the leading areas of the country and a south that struggles to reach the development levels of the center-north. In addition to highlighting the critical differences in geographical location of Industry 4.0 technologies, this research confirms the role of the accumulative effects derived from the concentration of the technological capabilities and of the spatial proximity to the knowledge production centers or to advanced firms. The factors of socio-economic marginality and those of a geographical one (morphology, position, etc.) further explain the picture of differences, even within the most advanced regions.

The aim of the next research will be to understand whether the need to rapidly adopt Industry 4.0 solutions will help to increase the gap between developed and marginal areas, or if on the contrary it will accelerate development processes in the short and medium term. The risk is linked to persistent or increasing divergences among different parts of Italy and policies may be important to ensure the diffusion of the benefits of Industry 4.0 and to manage the impact of advanced technologies in the different territorial contexts, including peripheral ones. In particular, it seems crucial to promote place-based policies, in terms of advanced infrastructures, technologies, support for businesses, material and digital accessibility, smart services, accompanied by territorial animation projects, enhancement of the quality of life, promotion of research, training and new entrepreneurship, which aims to achieve a dynamic of counter-trend and reduce inequalities..

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References

1. De Propis, L., Bailey, D. (eds.) Industry 4.0 and Regional Transformation. Routledge, London (2020)
2. Brynjolfsson, E., McAfee, A.: The Second Machine Age Work, Progress, and Prosperity in a Time of Brilliant Technologies. WW Norto, New York (2014)

3. Cipriani, A., Gramolati, A., Mari, G.: Il lavoro 4.0. In: La Quarta Rivoluzione Industriale e le Trasformazioni Delle Attività Lavorative. Firenze University Press, Firenze (2018)
4. Schwab, K.: The Fourth Industrial Revolution. World Economic Forum, Geneva (2016)
5. Marsh, P.: The New Industrial Revolution. Consumers, Globalization and the End of Mass Production. Yale University Press, New Haven (2012)
6. Balland, P., Boschma, R.: Mapping the potentials of regions in Europe to contribute to new knowledge production in Industry 4.0 technologies. Reg. Stud. **55**(10–11), 1652–1666 (2021)
7. Lazzeroni, M., Vanolo, A.: La nuova rivoluzione industriale tra smartness e crisi: le prospettive della geografia. In: Lazzeroni, M., Morazzoni, M. (eds.) Interpretare la quarta rivoluzione industriale: la geografia in dialogo con le altre discipline, pp. 87–100, 2020
8. Corradini, C., Santini, E., Vecciolini, C.: The geography of Industry 4.0 technologies across European regions. Reg. Stud. **55**(10–11), 1667–1680 (2021)
9. Azzari, M., Garau, C., Nesi, P., Paolucci, M., Zamperlin, P.: Smart city governance strategies to better move towards a smart urbanism. In: Gervasi, O., et al. (eds.) Computational Science and Its Applications – ICCSA 2018. Lecture Notes in Computer Science, vol. 10962, pp. 639–653. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95168-3_43
10. Iammarino, S., Rodriguez-Pose, A., Storper, M.: Regional inequality in Europe: evidence, theory and policy implications. J. Econ. Geogr. **19**, 273–298 (2019). https://doi.org/10.1093/jeg/lby021
11. Lazzeroni, E.M., Zamperlin, P.: Nuovi paradigmi tecnologici e impatto sui sistemi urbani tra convergenze e fratture. In: Dini, F., Martellozzo, F., Randelli, F., Romei, P. (eds.) Oltre la globalizzazione – Feedback, Società di Studi Geografici. Memorie geografiche NS 19, pp. 13–20. Firenze University Press, Firenze (2021)
12. Capello, R., Lenzi, C.: 4.0 technological revolution and economic competitiveness: unexpected opportunities for peripheral areas. Scienze Regionali, Italian J. Reg. Sci. **1**(2022), 13–36 (2022). https://doi.org/10.14650/103209
13. EPO: Patents and the Fourth Industrial Revolution. The global technology trends enabling the data-driven economy (2017 and 2020)
14. Martinelli, A., Mina, A., Moggi, M.: The enabling technologies of industry 4.0: examining the seeds of the fourth industrial revolution. Ind. Corportate Change **30**(1), 161–188 (2021)
15. Zamperlin, P., Garau, C.: Smart region: analisi e rappresentazione della smartness delle città metropolitane italiane. Bollettino AIC **161**, 59–71 (2017). https://doi.org/10.13137/2282-572X/21828