Economics of Innovation and New Technology

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/gein20

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To cite this article: Roberta Capello & Camilla Lenzi (25 Apr 2023): 4.0 Technological transformations: heterogeneous effects on regional growth, Economics of Innovation and New Technology, DOI: 10.1080/10438599.2023.2204523

To link to this article: https://doi.org/10.1080/10438599.2023.2204523

Published online: 25 Apr 2023.

ECONOMICS OF INNOVATION AND NEW TECHNOLOGY
https://doi.org/10.1080/10438599.2023.2204523

RESEARCH ARTICLE

4.0 Technological transformations: heterogeneous effects on regional growth

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ABSTRACT
Technological transformations based on 4.0 technologies are a reality. Despite this, there are few studies on their growth-enhancing role at regional level. This paper aims to fill this gap. By conceptually unpacking the two main technological transformations taking place – Industry 4.0 and the digital service economy – and identifying empirically the regions where they prevail, the paper examines whether the two transformations, despite of their profound different nature, are both conducive to regional growth in the period 2007–2018. Empirical results interestingly show that Industry 4.0 and automation technology adoption are associated with regional economic growth especially in those regions where such specific transformation prevails; differently, the effects from digitalisation spread all over European regions and regions where the digital service economy transformation prevails do not enjoy significant growth advantages with respect to others. Targeted regional policies are therefore called for by each transformation.

ARTICLE HISTORY
Received 30 October 2022
Accepted 3 April 2023

KEYWORDS
4.0 technological transformations; heterogeneous effects; regional economic growth

JEL CODES
O31; O33; R11

1. Introduction

A new technological era has been taking place in recent years based on the creation and large-scale diffusion of technologies such as artificial intelligence, robotics, internet of things, 3D printing, smart sensors, just to name a few of them (Brynjolfsson and McAfee 2014; McAfee and Brynjolfsson 2017; Schwab 2017; Frey and Osborne 2017).

The literature discussed extensively the impact of the diffusion of specific types of technologies. For example, the effect of robot adoption, both at the firm and at the spatial and national level, was largely analysed, highlighting the important economic and labour consequences of the increasing automation in the manufacturing environment (Büchi, Cugno, and Castagnoli 2020; Horváth and Szabó 2019; Acemoglu and Restrepo 2020). The same attention, however, has not been yet dedicated to other types of 4.0 technologies, like digitalisation. In this regard, most literature concentrates on the servitisation phenomenon, intended as the set of strategies and practices implemented by manufacturing firms to offer bundles of (digital) products and services (De Propris and Storai 2019; Lafuente, Vaillant, and Vendrell-Herrero 2019; Sforzi and Boix 2019), while the effects of digital technology adoption for specific forms of digital market transactions, like the sharing economy, have been less explored and documented, at least in large scale analyses (Frenken 2017; Frenken and Schor 2017; Schor 2016).

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Importantly, what has not yet gained interest in the literature is the analysis of the technological transformations taking place because of 4.0 technology adoption and their impacts. The focus on technological transformations, in fact, requires to go further with respect to the simple effects of technology adoption, and to analyse conceptually the structural reorganisation of production and business activities around new possible value creation channels – new manufacturing organisation, new business models and opportunities in both manufacturing and service sectors – pushed by the adoption of the new 4.0 technologies and expected to open vast economic growth opportunities (Ng, Ding, and Yip 2013).

Conceptually speaking, two main types of technological transformations can be easily identified. The first one relates to the manufacturing environment which is increasingly subject to a process of digitalisation, robotisation and automation, boosted by the development of digital value chains and the integration of physical and virtual systems, requiring the upgrading, if not the acquisition, of new managerial competencies within organisations (Lasi et al. 2014; Ciffolilli and Muscio 2018). This process is known and studied in the literature with the label of *Industry 4.0*, a term coined in 2011 in Germany at the Hannover Trade Fair as the name of the common initiative of the representatives of business, policy and science promoting the idea of strengthening the competitiveness of the German industry (Müller, Buliga, and Voigt 2018; Szalavetz 2019).

The second technological transformation relates to the redesigning of the boundaries of products towards services and of the enlargement of the different forms and modes with which final services are created and delivered through digital technologies, a transformative process defined as the *digital service economy* (Capello, Lenzi, and Panzera 2022a). The adoption of the new digital technologies stretches the boundaries between products and services, with the latter not only complementing and/or enriching the former, as proposed in the case of servitisation and its literature (Rabetino et al. 2021 and Baines et al. 2017), but also, and increasingly, *substituting* each other, with dramatic consequences for competitive dynamics and value creation and income distribution mechanisms.

Both technological transformations are associated with high expectations in terms of growth potentials, as their diffusion opens new sources of value and wealth creation and, therefore, economic growth (Brynjolfsson, Hui, and Liub 2019). If this is true at the world scale, the effects of the two transformations can be heterogeneous for local economies. With the onset of Industry 4.0, the robotisation of manufacturing firms is expected to increase the efficiency and quality of products (Camagni, Capello, and Perucca 2022), with the consequence of enhancing their competitiveness and that of the area in which firms are located. The digital service economy, as well, is expected to have an increase in the efficiency of market transactions; this increased efficiency, however, does not necessarily promote expansionary effects and economic growth at the local scale. In fact, while digital intermediaries, i.e. the digital platform owners, generally located outside Europe, can enjoy high profitability gains (Rullani and Rullani 2018; Srnicek 2016), European regional economies can be left either with no advantage or, in the worst case, with the negative effects because of the displacement of local traditional (offline) business activities (Müller, Buliga, and Voigt 2018) and jobs (Capello, Lenzi, and Panzera 2022b).

Even if evidence is expanding fast in the very last years, it does so in a fragmented way frequently dealing with a specific transformation, e.g. the transformation of the manufacturing fabric discussed in the literature on the product service economy, servitisation and Industry 4.0 (De Propris and Bailey 2020; Barzotto et al. 2019; Dauth et al., 2021); specific technologies e.g. artificial intelligence (Edquist, Goodridge, and Jonathan Haskel 2021), green technologies (Cicerone et al. 2022); specific areas, e.g. industrial districts (Burlina and Montresor 2022) or specific European countries, e.g. Hungary (Szalavetz 2019), France (Acemoglu, Lelarge, and Restrepo 2020), Italy (Büchi, Cugno, and Castagnoli 2020). In fact, empirical evidence proving the effects of the different technological transformations on GDP growth still lags behind conceptual reflections especially when the regional dimension of analysis is taken into consideration. More generally, an overarching analysis of the technological transformations in place and of their impacts on regional economies has not been proposed yet.

This paper, then, aims to fill this gap by providing an assessment of the local effects of 4.0 technological transformations. Specifically, by presenting an operational definition of technological transformations, the paper offers (i) a mapping of technological transformations in European regions, (ii) a grouping of regions, based on cluster analysis, distinguishing between regions in which the most important transformations prevail (i.e. the digital service economy or Industry 4.0) from those where such transformations are still embryonic, (iii) an econometric analysis, based on an augmented regional growth equation, aimed to test whether the expected positive economic effects largely conceptualised in the literature (Brynjolfsson and McAfee 2014; McAfee and Brynjolfsson 2017; Schwab 2017) are likely to take place and to differ between transformations. Interestingly, findings are not only of relevance for the scientific debate, especially at the regional level, but also raise some warnings for policy makers. In fact, the growth-enhancing effects of the Industry 4.0 transformation and automation technology adoption are found to be selective in space and concentrated in those regions where such transformation prevails and is pervasive. Differently, the effects from the digital service economy are not particularly significant where such transformation prevails, yet pervasive digital technology adoption seems conducive to economic growth all over European regions.

The rest of the paper is organised as follows. Section 2 presents the two main technological transformations and discussses their spatially heterogeneous growth-enhancing role. Section 3 deals with the operational definition of technological transformations and their measurement in European regions. Section 4 describes the econometric framework and discusses the results on the growth of European (EU27 + UK) NUTS2 regions. Section 5 concludes the paper with some final remarks and suggestions for policy.

2. Technological transformations and their spatially heterogeneous growth opportunities

Technological transformations are intended in this work as all structural changes in the economy that take place through technology adoption and generate new value creation channels, new business modes, new sources of efficiency advantage for economic actors. Such actors, interpreted as either entrepreneurs, firms or local economic systems, cannot skip such changes, and have to transform themselves to thrive on the market (Capello and Lenzi 2021a).

Conceptually speaking, therefore, technological transformations go beyond the mere adoption of new technologies and imply profound changes in the way business is done and economic value is created. Accordingly, measuring their impact on local economies requires focusing the attention on the effects that the new structure of the economy obtained through the adoption of 4.0 technologies generates on local dynamics rather than on those of technology adoption only.

As mentioned above, conceptually speaking, two main technological transformations can be identified.

The first relates to Industry 4.0, mainly occurring in the manufacturing sectors. Especially in sectors organised around batch productions, robotisation, automation and digitalisation allow the development of the smart factory model, based on a combination of advantages of scale and scope, favouring the penetration if not the opening of unexplored market niches and a general expansion of market size and share (De Propris and Bailey, 2020). Many scholars have documented the positive effects of the adoption of new business models on the market share of adopting firms with robust results across regions, sectors and countries (Dauth et al. 2021; Acemoglu, Lelarge, and Restrepo 2020; Szalavetz 2019).

Positive effects from Industry 4.0 transformation do not benefit adopting firms only. In fact, the presence in a region of several firms able to transform their production processes and business models can represent an important boost to wealth creation and thus economic growth (Müller, Buliga, and Voigt 2018; Antonietti et al., 2022). Additionally, adopting firms are frequently superstar firms that can contribute disproportionately to the economic fortunes of the place where they locate (Autor et al. 2020). Importantly, also co-located firms can enjoy enlarged growth opportunities, because of input-output linkages. Suppliers and customers linked to the expanding firms can in fact experience improved and enlarged market opportunities, if not an increase of their respective market shares. Higher market shares, revenues and profits can therefore sustain economic growth at the local level.

Accordingly, it is reasonable to expect that *most, if not all, economic advantages, in terms of economic (i.e. GDP) growth, from Industry 4.0 are selective in space, in that they take place in the region where this transformation prevails and automation technology adoption is pervasive (Hypothesis 1)*.

A different situation characterises the second transformation, namely the digital service economy, defined as an economy encompassing various sets of businesses, enabled by digital platforms, redesigning the boundaries of products towards services (Capello, Lenzi, and Panzera 2022a). More specifically, the digital service economy refers to the idea that the full-scale digitalisation trend characterising modern economies and society is redesigning the boundaries between products and services, with the latter not only complementing and/or enriching the former but also, and increasingly, *substituting* the former. The dematerialisation of products (e.g. a CD) into their own contents (e.g. music) allows the last one to be sold online in the form of a digital service (e.g. a subscription to Spotify), wiping out the market of the original products in favour of the newly created services.

This transformation mostly rests on digital market transactions. Digital platforms enable the creation of new online markets, and include phenomena as diverse as the sharing economy (e.g. BlaBlaCar), the online service economy (e.g. Uber) up to the digital content economy (e.g. Spotify, Netflix). Regardless of the specificities of each form of digital service economy, they all enable expanding the opportunities and choices of consumers to get a product and/or a service and generate widespread benefits for users and (independent) service providers, independently of their localisation in advanced regions or in more remote and peripheral ones. All this is made possible by intermediary platforms that match users to service providers, frequently, temporary or part-time workers, if not freelancers, who are willing to participate in the market to obtain some earnings by offering their spare time and skills since it is relatively fast, frictionless and cheap (e.g. Uber drivers or Deliveroo riders, commonly known in the literature and in the press as gig workers (Stanford 2017; Kenney and Zysman 2016)). Digital platforms, then, replace bilateral with trilateral relationships, involving a provider (of jobs, contents, services), a user, and the platform (Koutsimpogiorgos et al., 2020; Capello, Lenzi, and Panzera 2022a). A digital platform can therefore be defined as a 'matchmaker' between providers who offer a production capacity and users interested to use, buy, or enjoy it (Kornberger et al., 2017).

As in the case of the Industry 4.0 transformation, the spatial distribution of the digital service economy effects depends on the geography of the actors involved in this transformation. In the case of the Industry 4.0 transformation, this mapping can be relatively easy and largely depends on the localisation of manufacturing firms switching to the new business models and practices and adopting the new (automation) technologies (De Propris and Bailey, 2020). In the case of the digital service economy, this mapping is more complex as it depends on the localisation of the three main parties involved in online transactions, i.e. digital intermediaries, service providers and service users (Koutsimpogiorgos et al., 2020; Capello, Lenzi, and Panzera 2022a; Cersiola and Panzera, 2022).

Starting with digital platform owners, they do enjoy the largest share of value created online (Srnicek 2016; Stanford 2017; Autor et al. 2022). In principle, therefore, they could influence profoundly the economic fortunes of the places where they are located. However, digital platforms tend to be particularly footloose, highly strategic in their location choices and sensitive not only to labour pooling and more generally agglomeration advantages but also (if not primarily) to fiscal discount incentives (Srnicek 2016; Koutsimpogiorgos et al., 2020). More generally, they tend to be located outside Europe, and in any case not necessarily they do co-locate with most of their providers and end users. Put shortly, their growth-enhancing role can be virtually nil in the European context, especially at the regional level.

Looking at online service providers, regions where they are predominantly concentrated and which host the digital service economy transformation do not necessary show higher growth with respect to other regions. The high competition between offline and online activities in regions where such a technological transformation takes place can reduce growth effects (McAfee and Brynjolfsson 2017; Rullani and Rullani 2018; Aghion et al. 2019), leading to similar advantages in such transformative areas with respect to all others. Moreover, the expected growth from an increase in market size from digital technology adoption has not been empirically verified (Capello, Lenzi, and Perucca 2022).

Importantly, digital service providers can easily be located all over the place. The connection to digital platforms, available everywhere, enables the large-scale, ubiquitous accessibility to digital markets for both providers and end users; in this respect, the digital service economy is able to generate widespread benefits not only in the most transformative regions, but also in remote and less transformative ones (Dudley, Banister, and Schwanen 2017). By boosting online market transactions, expansionary effects can be triggered, leading to growth advantages which are not necessarily strongly localised and, thus, undifferentiated across places.

Put shortly, the growth effects of the digital service economy transformation are in principle high but not concentrated where such technological transformation prevails. This is because of the scant presence of digital titans in the European context, and of the widespread presence of service providers and users. Still, the widespread availability and use of digital technologies necessary for digital transactions can generate positive effects on regional economic growth everywhere.

Accordingly, it is reasonable to expect that *regions where the digital service economy transformation prevails do not necessarily accrue higher growth advantages with respect to other regions; yet, the advantages from pervasive digital technology adoption can spread throughout European regions (hypothesis 2)*.

The empirical verification of these hypotheses requires, therefore, an operational definition of technological transformations, presented in the next section.

3. Technological transformations: conceptual definition and measurement

Technological transformations are primarily a sector-driven phenomenon, and therefore require a sector-driven conceptual and measurement approach. In fact, differences among sectors in terms of profitability gains from adoption can easily explain the propensity and/or vulnerability of each sector to transformation (Malerba 2002). Applying this reasoning, the identification of a technological transformation rests on the presence of specific sectors that are prone to a technological transformation. In this perspective, two main critical and intertwined elements influence the potential profitability gains and, thus, the probability of adoption with differentiated outcomes across sectors, namely the characteristics of the production process and, relatedly, the intensity of use of specific inputs in the production process, whose use is especially advantageous in the new technological landscape.

Specifically, an important distinction can be made between sectors based on continuous vs. batch production processes. Connectivity and interaction between parts, machines and people are able to make the production system faster and more efficient and strengthen mass customisation at peak levels, when production processes are organised in batches. Instead, the efficiency gains achievable by merging different production phases are more limited when production processes are already much integrated, as in the case of continuous production processes.

Another sectoral distinction refers to the different intensity in the use of the 'key factor' in a production process. According to Perez (1983), the 'key factor' is that particular input factor which is most affected in terms of cost abatement by the new technologies. The intensity of the 'key factor' makes the adoption of the new technologies especially appealing, rewarding and profitable. In the case of the 4.0 technological revolution, the 'key factor' is the digital elaboration and transmission of large volumes of data, information, communication and texts. The degree of exploitation of this 'key factor' differs among sectors, explaining the penetration of the technologies and of the related transformations.

The mix of sectors in a region therefore determines the probability for a technological transformation to pervade the local economy. The greater the specialisation in those sectors in which the gains from adoption are high, the wider the potential for technological transformation. In this respect, manufacturing sectors and services can be conceptually divided in three main groups (Capello and Lenzi 2021b):

- the *technology manufacturing sectors and services*, which manufacture and/or supply the new technologies. These sectors are in charge of maintaining and increasing the relative cost advantage of the new technologies and ultimately shape the rhythm of penetration of technological transformations in the economy;
- the *carrier manufacturing sectors and services*, which represent the most intense and active users of the new technologies and, thus, are those best positioned to grasp the advantages of the technological revolution and of the new production styles, also by implementing co-innovation strategies (Von Hippel 2005);
- the *induced manufacturing industries or services*, which are users of the new technologies but, in relative terms, enjoy more limited advantages from the technological revolution because their production structure is less intensive of the new technologies. These sectors adopt the new technologies (though less intensively) to provide their products and services through different (digital) channels. Adoption enables profitability gains, even if less than in carrier sectors.

Accordingly, the higher the regional specialisation in technology and carrier manufacturing sectors, respectively services, the greater the potential of Industry 4.0 transformation, respectively digital service economy transformation.

On empirical grounds, the classification into technology, carrier and induced sectors (according to the NACE Rev 2.2 classification at the 2-digit level) follows the OECD partitioning of sectors according to their digital intensity level (Calvino et al. 2018). Specifically, technology and carrier sectors are those with high or medium-high digital intensity, whereas induced sectors are those with low or medium-low digital intensity. Additionally, technology and carrier sectors were distinguished according to the degree of 4.0 patent intensity[1] in each NACE Rev 2.2 sector. Table 1 reports the exact sectoral classification.

Regional specialisation in technology, carrier and induced sectors has been measured through location quotient (LQ) indicators computed on employment data in the three different groups of sectors and by distinguishing between manufacturing and service sectors, based on regional sectoral employment data from Eurostat Structural Business Statistics in the 2008–2016 period.[2]

Importantly, regions can be specialised in all sectors, in only one, or in none of them, suggesting that Industry 4.0 and the digital service economy transformations can co-exist in real local economies, though with different pervasiveness depending on the intensity of adoption of the technologies specific of each transformation, but also that regions may experience embryonic technological transformations if not lack them at all.

In order to identify whether a specific technological transformation is prevailing over the other or whether, instead, a region is at the margins of the present transformations, a k-means cluster analysis has been performed on the six regional sectoral specialisation variables (i.e. specialisation in each of three manufacturing sectors and in each of the three services). In the choice of the final number of clusters to be retained, particular attention was placed on the balance between the within- and between-cluster variance, as well as on the portion of observations in each cluster, particularly relevant for the interpretability of results in terms of 4.0 technological transformation patterns. Both aspects were important to uncover with a sufficient granularity the heterogeneity of European regions while preserving the statistically significant differences across patterns. The partitioning

Table 1. Technology, carrier and induced sectors in manufacturing and services.

	Technology and carrier sectors	Induced sectors
Industry	Manufacture of wood and paper products and printing, furniture (16-17-18-31)	Manufacture of food, beverages, tobacco products (C10-11-12)
	Manufacture of computer, electronic and optical products (C26)	Manufacture of textiles, wearing apparel, leather (C13-14-15)
	Manufacture of electrical equipment (C27)	Manufacture of coke and refined petroleum products (C19)
	Manufacture of machinery and equipment (C28)	Manufacture of chemicals and chemical products (C20)
	Manufacture of transport equipment (C29-30)	Manufacture of pharmaceutical products (C21)
	Other manufacturing, repairs of computer (C32-33)	Manufacture of rubber and plastics products, and other non-metallic mineral products (C22-23)
		Manufacture of fabricated basic metal and fabricated metal products (C24-25)
		Agriculture, Forestry and Fishing (A)
		Mining and Quarrying (B)
		Electricity, gas, steam and air conditioning (D)
		Water Supply; Sewerage, Waste Management and Remediation Activities (E)
		Construction (F)
Services	Wholesale and retail trade, repair (G)	Transportation and Storage (H)
	Information and Communication (J)	Accommodation and Food Service Activities (I)
	Professional, Scientific and Technical Activities (M)	Real Estate Activities (L)
	Administrative and Support Service Activities (N)	Education (P)
	Public Administration and Defence; Compulsory Social Security (O)	Education (P)
	Arts, entertainment and recreation (R)	Human Health and Social Work Activities; residential care and social work activities (Q)
	Other Service Activities (S)	

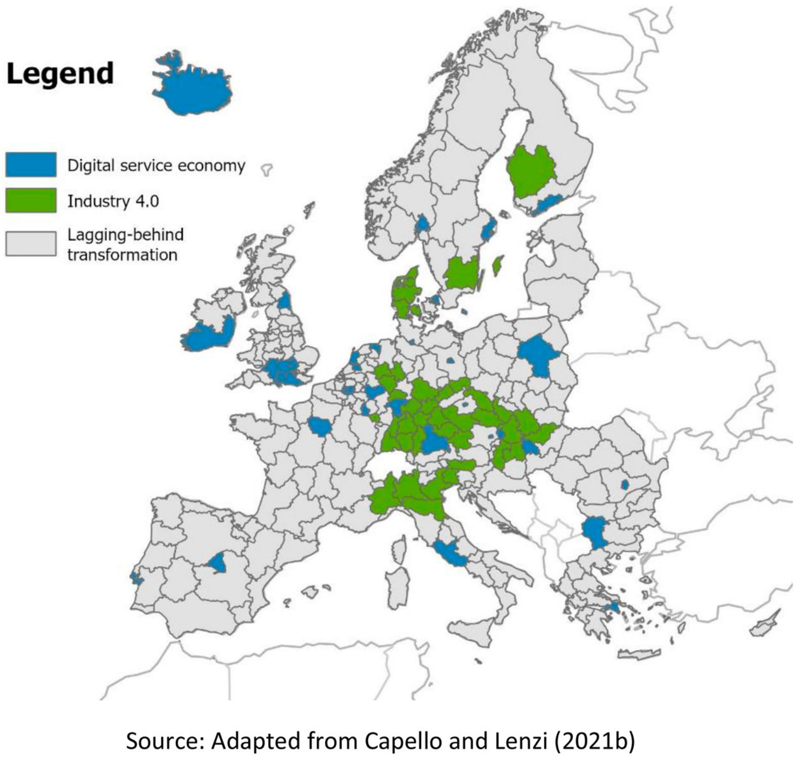
Notes.
1) Sectors are defined as technology or carrier if in at least one of two periods examined by Calvino et al. (2018), i.e. 2001–2003 or 2013-2015, they are classified as of high or medium-high digital intensity.
2) In bold, technology sectors, i.e. high patent intensity in 4.0 technologies.
3) Nace Rev. 2.2 2-digit code in parentheses.

obtained was robust to alternative extraction based on different similarity measures and on different initial group centres, with a limited number of regions being reassigned to other clusters. Its results have been interpreted through a series of variables measuring the regional sectoral adoption intensity and the regional transformation enabling conditions on the basis of an ANOVA analysis. The description, measurement and sources of variables used in the cluster and ANOVA analyses are presented in Table A1 in appendix.

Accounting for the intensity of adoption in the most transformative sectors is highly important; in fact, regions may considerably differ in their innovation and adoption capacity despite a similar specialisation profile. Specifically, sectoral specialisation has to match a high intensity of local technology adoption in technology and carrier sectors to make a technological transformation become pervasive in a region. A favourable regional sectoral mix, in fact, can be insufficient in absence of learning, innovation and adoption processes within the existing technology and carrier sectors.

In particular, two indicators have been taken into consideration, accounting respectively for the adoption intensity of automation technologies and digital technologies in each of the three (i.e. technology, carrier and induced) manufacturing and service sectors. For what concerns the regional transformation enablers, several dimensions have been considered, including education, creativity and technology creation, entrepreneurial spirit, digital literacy, urbanisation, exposure to job automation, among others. Regions better endowed in these respects are, therefore, more likely to be subject to Industry 4.0 or digital service economy transformations.

The cluster analysis enabled distinguishing those regions in which the most important transformations prevail (i.e. the digital service economy or, alternatively, Industry 4.0), from those regions where such transformations are still embryonic, labelled in what follows as lagging-behind



Map 1. Industry 4.0 and Digital Service Economy in European Regions.
Source: Adapted from Capello and Lenzi (2021b).

transformation regions (Map 1). The latter comprises three different groups of regions, in which transformations are not yet fully fledged. In total, therefore, five distinctive set of regions were identified by means of cluster analysis; for the purpose of the paper, however, the interest lies in the comparison of those groups experiencing the deepest transformations against the others. Table A2 presents the mean values by cluster for the variables used in the cluster and ANOVA analyses.

As largely expected, the digital service economy is primarily a metropolitan phenomenon and figures prominently in regions hosting large and capital cities, in both Western and Eastern European countries (Map 1). Metropolitan areas are, in fact, commonly considered the hub of innovation and technological change and the main centre for research activities (Carlino, Chatterjee, and Hunt 2007). Digital service economy regions show the highest specialisation in technology and carrier services and a relatively high level of technology adoption in their sectors of specialisation, especially carrier services. Moreover, this group of regions rank first according to multiple dimensions of transformation enabling conditions: education, digital literacy, innovation and entrepreneurship, and 4.0 patenting, especially in technology (manufacturing and service) sectors.

Industry 4.0 transformation concentrates in Southern Germany and Northern Italy, as well as in Central European countries strongly integrated in the German manufacturing value chains (e.g. in Czech Republic, Slovakia, Hungary) (Szalavetz 2019). These regions share a historically strong tradition in advanced manufacturing (e.g. automotive). Industry 4.0 regions are characterised by a high specialisation in technology and carrier manufacturing sectors and show the highest adoption of industrial robots in both specialisation sectors. Technology adoption is particularly high for both manufacturing and digital service technologies, showing the presence of strong spillovers across sectors and transformations involving economic activities linked either upstream or downstream with specialisation ones. Consistently with their non-metropolitan location, Industry 4.0 regions present a weaker endowment than digital service economy ones in terms of enabling conditions for transformation such as population educational level and digital literacy, innovation, entrepreneurship. Both transformations, however, have quite a limited diffusion; this finding is quite surprisingly given the large attention received in the literature especially by the Industry 4.0 transformation.

The next section presents the econometric framework applied to test the importance of these technological transformations for the growth of European NUTS2 regions.

4. Technological transformations and regional growth: methodology and results

4.1. The econometric framework

The test of the two hypotheses set out in section two followed a two-step analysis.

Firstly, in order to test whether the two technological transformations generate growth advantages for the regions where they prevail (as expected in the case of the Industry 4.0 transformation – hypothesis 1) or not (as expected in the case of the digital service economy one – hypothesis 2), a stylised regional growth equation was estimated in which the key explanatory variables account for the transformation pattern characterising each region (i.e. digital service economy, Industry 4.0 or none of them for the lagging behind transformation regions). Second, to boost confidence in the results obtained and in their interpretation, the regional growth equation was expanded to include two variables accounting, respectively, for the adoption intensity of automation and digital technologies. The focus was purposely on these technologies being the former key enabler and distinctive element of the Industry 4.0 transformation (see among many others Dauth et al. 2021) as much as the latter are fundamental for the digital service economy one (see among many others Kenney and Zysman 2016). The introduction of these variables follows the expectation that technological transformations are more intense the greater is the intensity of adoption of their target technologies (Perez 2010). Importantly, the interaction terms between each of the technology adoption variables with the technological transformation ones allows confirming the spatially selective or universal impact of alternative technology adoption on regional GDP growth.

Specifically, the regional GDP growth rate ($\Delta GDP_{r,t1\text{-}t0}$) was measured between the last (t_1) and the beginning year (t_0) of each of the two periods considered (i.e. 2007–2012 and 2013–2018). The first period accounts for the years of the crisis with the dependent variable measured in the period 2007–2012 and the explanatory variables measured at the beginning of the period (i.e. 2007, or the least recent year when this was not feasible). The second period accounts for the years of the recovery with the dependent variable measured in the period 2013–2017 and the explanatory variables measured at the beginning of the period (i.e. 2013).

The exact specification of a regional growth equation is still a matter of debate and is subject to the specific focus of the analysis (Rodríguez-Pose and Crescenzi 2008; Capello and Lenzi 2019, Dellisanti, 2023). In the effort to mark off the specific role of regional technological transformations, but also to keep a relatively parsimonious set of controls, the estimated regional growth equation has been augmented by including a set of control variables $X_{r,t0}$ aimed at accounting for:

- the initial level of GDP and population, in order to control for possible convergence trends and the size of the region (Quah 1996; Pina and Sicari 2021),
- agglomeration economies, accounted for by the share of population living in metropolitan areas; cities are innovation hubs and tend to growth more than peripheral settings (Carlino, Chatterjee, and Hunt 2007; Combes et al. 2012),
- the level of education and skills to account for the regional human capital, measured through the regional population educational attainment level (Gennaioli et al. 2013; Rodríguez-Pose and Crescenzi 2008),
- the technological progress in a region and its absorptive capacity, captured through the regional innovativeness intensity (Sterlacchini 2008; Edquist, Goodridge, and Jonathan Haskel 2021),

- the occupational mix in a region, measured by the share of automatable jobs in the region; automatable jobs are primarily concentrated in less technology-intensive sectors and less-skilled occupations, two conditions frequently associated with weaker growth potential (Arntz, Gregory, and Zierahn 2018),
- the presence in the EU for a long period, which accounts for the country level of development, captured through a dummy variable flagging EU15 countries (Camagni et al. 2020),
- the period of time, captured by a dummy variable, to control for the effect of the 2007–2009 and 2011 crises (Mazzola and Pizzuto 2020).

The key explanatory variables are three dummies. The first one flags regions where the digital service economy is the prevailing technological transformation, the second one flags regions where Industry 4.0 is the prevailing technological transformation; the third one (the reference case in the regressions) flags the lagging-behind transformation regions.

Equation (1) summarises the estimated stylised growth equation:[3]

$$\Delta GDP_{r,t1-t0} = F(X_{r,t0}) + \beta \,\text{Technological Transformation}_{r,t0} + u_r + \varepsilon_{r,t0} \tag{1}$$

As noted above, this specification has been next expanded in order to include two variables capturing automation and digital technology adoption intensity, and their interaction terms with the technological transformation dummies; the interaction terms allow testing the effects of each technological transformation pervasiveness and grasping the spatially heterogeneous or universal impacts of technology adoption on GDP growth across transformations.

Specifically, Equation (1) has been expanded as follows:

$$\begin{aligned} \Delta GDP_{r,t1-t0} = {} & F(X_{r,t0}) + \beta \,\text{Technological Transformation}_{r,t0} + \gamma \,\text{adoption}_{r,t0} \\ & + \delta \,\text{Technological Transformation}_{r,t0} \times \text{adoption}_{r,t0} + u_r + \varepsilon_{r,t0} \end{aligned} \tag{2}$$

Specifically, the technology adoption variable is measured using two different indicators. The adoption of automation technologies is captured by the robot sectoral penetration rate, in line with the literature (see among many others Acemoglu and Restrepo 2020). National data sourced from the International Federation of Robotics (IFR) was apportioned at the regional level by using a set of three weights accounting for the regional employment share in manufacturing, the regional diffusion of broadband and the regional presence of manual occupations (i.e. blue-collar jobs).

Digital technologies instead were measured as the share of regional firms with at least 1% turnover from online sales. National data sourced from the EUROSTAT was apportioned at the regional level by using a set of two weights accounting for the regional employment share in private services and the regional share of individuals using internet. The selection of this indicator is consistent with the EUROSTAT[4] and OECD[5] approaches and is intended as a measure of the adoption of digital technologies and of the capacity to shift to online markets as primary locus for market transactions.

The operationalisation of the concept of digital technologies and digitalisation can be debatable due to the complexity and multifaceted nature of the phenomenon. The solution adopted in the paper, however, is the outcome of several considerations. In the literature, one of the most frequently used variables for measuring digitalisation is patent intensity in advanced digital technologies, e.g. artificial intelligent (Cicerone et al. 2022). However, patents represent inventions, the most cutting-edge ones, but they do not necessarily go in tandem with adoption, especially in services which typically rank low in patenting (Tether 2015). This option, therefore, was not particularly attractive in the present case.

Having excluded the use of patents, then, data availability and cross-country comparability dictated important constraints in the choice of the final indicator of digitalisation, i.e. the share of firms with at least 1% turnover from online sales. First, this indicator is part of DESI (Digital

Economy and Society Index) developed by the EU for its member states,[6] and of the multi-dimensional digital intensity index developed by the OECD at the sectoral level (Calvino et al. 2018), ensuring then a wide coverage of countries over time. Moreover, this indicator overcomes some of the limits of more traditional ones such as investments in ICT equipment and ICT personnel (Calvino et al. 2018), both widely used in the literature, by emphasising the distinctive aspect and novelty of modern digitalisation compared with the past ICT revolution, i.e. the shift towards online markets as the primary channel for market transactions and not simply the ICT endowment (Capello, Lenzi, and Panzera 2022a). Additionally, the use of more advanced and recent digital technologies, e.g. data analytics, still suffer from important comparability constraints over time, countries and regions, partly due to their newness and their limited, though increasing, diffusion. Even if 1% of revenues from online sales may look at a first glance as a too low threshold to identify digital technology adoption, this concern may not be particularly acute in this setting given the years considered in the analysis, when online commerce was not as diffused as nowadays especially in some Southern and Eastern European countries. These considerations, therefore, sufficiently support the use of this indicator as the most convincing option for the present analysis.

Table 2 reports description and summary statistics for the main explanatory variables and the controls.

The econometric analysis was performed in the frame of a random effect panel setting consisting of two periods. Random effects rather than fixed effects were adopted because of the presence of time-invariant explanatory variables (i.e. the different types of technological transformations and the EU15 dummy variable). In consideration of the possible spatial interdependencies across regional units, we followed the general-to-simple model selection rule and the test procedure proposed by Elhorst (2010) to decide whether and which spatial model is the most appropriate in the present empirical context. We start by estimating an SDM by using a row-standardized spatial weight matrix whose elements, the w_{ij} spatial weights, represent the row-standardised inverse distance between the centroids of the i and j regions. In all model specifications, the significance of the

Table 2. Description and measurement of the variables.

Variables	Measurement	Years	Source	Mean	Std. dev	Min	Max
GDP growth rate	Average annual compound growth rate	2007-2012; 2013–2017	EUROSTAT	0.97	2.10	−8.04	11.74
GDP	GDP (million euros)	2007; 2013	EUROSTAT	491.7	567.4	262.4	6247
Population	Number of inhabitants (thousands)	2007-2009; 2010–2012	EUROSTAT	1,891	1,508	125	11,960
Urbanisation	Share of population living in metropolitan areas	2007; 2013	EUROSTAT	48.62	34.21	0	100
Education	Share of 25–64 age population with tertiary education	2007; 2013	EUROSTAT	25.52	9.16	7.3	69.8
Innovation	Number of trademarks per 1,000 inhabitants	Average 2008–2010 and 2010–2012	EUROSTAT	0.12	0.14	0	1.84
High risk of automation	Share of jobs at high risk of automation	2011	OECD-PIIAC and EUROSTAT; authors estimation	16.87	7.69	4.33	46.43
FDI	Amount of FDIs per 1,000 inhabitants	Two values: 2003–2005 and 2005–2007	FDI-Regio, Bocconi-ISLA	0.10	0.24	0	3.36
Robot adoption	Robot per 1,000 employee	Average 2009–2011 and 2011–2013	IFR, EUROSTAT	0.39	0.34	0.003	1.71
Online sales	Share of firms selling online, at least 1% of turnover	Average 2009–2011 and 2011–2013	EUROSTAT	22.35	8.5	4.61	40.33

The number of observations is 526 (263 regions x 2 periods of time). Descriptive statistics computed over the 2007–2018 spatially lagged dependent variable (tested in the SDM specification) is rejected, as is the joint significance of the spatially lagged independent variables. In this case, Elhorst's (2010) method suggests that the disturbances should be tested for spatial dependence. In the present model specification, tests do not allow rejecting the null hypothesis of absence of spatial dependence in the disturbances, supporting the use of Generalised Least Squares (GLS) random effects estimates. The estimates reported in the next section, then, are based on robust GLS.

The following section comments on results of the estimation of the effects of different technological transformations on GDP growth.

4.2. The results

Estimates of the impact of technological transformations on regional GDP growth are reported in Table 3. Starting with the base model specification (Table 3, Model 1), estimates highlight that, with respect to lagging-behind transformation regions, Industry 4.0 transformation areas do enjoy a growth premium. Intense robotisation, automation and digitalisation processes within manufacturing firms can boost competitiveness and turn into superior growth for those regions where firms embracing the Industry 4.0 transformation are located, in line with the literature in this field (De Propris and Bailey 2020), as posited by hypothesis 1. A different story instead applies for regions where the digital service transformation prevails, which do not enjoy a growth premium with respect to the lagging behind transformation. This result can look at a first sight quite striking; however, there might some channels hindering or least mitigating the positive effects expected from such transformation. First, firms undertaking the digital service economy transformation are subject to fierce competition from digital titans located outside Europe, a condition that may limit the growth advantages at the regional level; second, the digital service economy may amplify the competition between local online and offline activities, an additional condition that may compress the growth advantages at the regional level.

To shed further light on the role of the pervasiveness of each transformation and to prove further the hypotheses set out in Section 2, Model 2 in Table 3 introduces the two technology adoption variables, which both turn to be positively associated with regional growth. As long as digital platforms enable the large-scale, ubiquitous accessibility, low price, super-fast transactions, and efficient digital services, the number of digital market transactions can enlarge and bring diffused expansionary effects and growth advantages. Similarly, the adoption of automation technologies is conducive to growth, a result consistent with the literature (Dauth et al. 2021).

Interestingly, interacting the digital technology adoption variables with the three dummies each capturing one of the three different technological transformation patterns confirms the positive association between a generalised shift towards digital market transactions in a region and its economic growth, irrespective of the specific transformation characterising a region. In fact, while the importance of a diffused digitalisation for regional growth persists, the interaction terms between the variable measuring the intensity of digital technology adoption and each of the three technological transformation dummy variables are all not significant, highlighting the absence of growth advantages specific of a particular technological transformation (Table 3, Models 3–5).

Differently, interacting the automation technology adoption variable with the three dummies each capturing one of the three different technological transformation patterns highlights heterogeneous effects across regions characterised by different technological transformations. While the importance of a diffused automation for regional growth persists, the effect is substantially larger in the case of Industry 4.0 with respect to the others and considerably lower in the case of digital service economy regions, suggesting that the growth advantages from automation technology adoption are selective in space (Table 3, Models 6–8).

This finding enables some policy reflections presented in the conclusive section.

Table 3. Growth Premium in Industry 4.0 and in the Digital Service Economy regions.

Dependent variable: real GDP growth	1	2	3	4	5	6	7	8
GDP (log)	−0.008**	−0.013***	−0.013***	−0.013***	−0.013***	−0.013***	−0.012***	−0.013***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Population (log)	0.010***	0.015***	0.015***	0.015***	0.016***	0.016***	0.014***	0.016***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Education (%)	0.045***	0.027**	0.027***	0.028***	0.028***	0.028***	0.025**	0.028***
	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Innovation (trademark intensity)	0.038***	0.041***	0.042***	0.042***	0.042***	0.044***	0.041***	0.043***
	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)	(0.013)	(0.012)	(0.012)
Metropolitan population (%)	0.004**	0.001	0.001	0.001	0.001	0.000	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Risk of automation (%)	−0.038***	−0.033***	−0.033***	−0.033***	−0.033***	−0.033***	−0.033***	−0.032***
	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
FDI	−0.006*	−0.003	−0.003	−0.003	−0.003	−0.004	−0.003	−0.003
	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)
Digital service economy	−0.004	0.000	0.006	0.006				
	(0.003)	(0.003)	(0.008)	(0.004)				
Industry 4.0	0.003*	0.000		0.002			−0.005	
	(0.002)	(0.002)		(0.005)			(0.004)	
Lagging-behind transformation					−0.004			−0.003
					(0.005)			(0.003)
Digital technology adoption		0.063***	0.066***	0.064***	0.052***	0.062***	0.062***	0.064***
		(0.011)	(0.011)	(0.012)	(0.017)	(0.010)	(0.011)	(0.011)
Automation technology adoption		0.458**	0.459**	0.467**	0.480**	0.731***	0.364	0.082
		(0.231)	(0.233)	(0.229)	(0.238)	(0.210)	(0.234)	(0.446)
Digital service economy x digital technology adoption			−0.022					
			(0.030)					
Industry 4.0 x digital tech. adoption				−0.006				
				(0.019)				
Lagging-behind transformation x digital technology adoption					0.016			
					(0.019)			
Digital service economy x automation technology adoption				−1.346**				
				(0.584)				
Industry 4.0 x automation technology adoption					0.856*			

(*Continued*)

Table 3. Continued.

Dependent variable: real GDP growth	1	2	3	4	5	6	7	8
					(0.517)			
Lagging-behind transformation x automation technology adoption						0.554		
						(0.430)		
EU15	−0.019***	−0.018***	−0.018***	−0.018***	−0.018***	−0.018***	−0.019***	−0.018***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Period 2013–2018 dummy	0.022***	0.021***	0.021***	0.021***	0.021***	0.021***	0.021***	0.021***
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Constant	−0.098***	−0.150***	−0.154***	−0.150***	−0.152***	−0.158***	−0.140***	−0.155***
	(0.034)	(0.037)	(0.035)	(0.039)	(0.037)	(0.036)	(0.039)	(0.038)
Wald test (joint) – spatial lag of the independent variables (*p*-value), SDM	0.14	0.25	0.23	0.26	0.24	0.23	0.23	0.27
Wald test – spatial error (*p*-value), SEM	0.77	0.88	0.81	0.89	0.87	0.79	0.88	0.85
R2	0.54	0.58	0.58	0.58	0.58	0.58	0.58	0.58

Notes: $N = 522$. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Control variables show the expected sign and significance, highlighting a process of convergence, a recovery in the second period, a more intense growth in Eastern Europe and the importance of the education, innovation and a favourable occupational mix, with a limited fraction of automatable jobs.

5. Conclusions

This paper has analysed the impact of the present technological transformations, i.e. Industry 4.0 and digital service economy, on the economic growth of European regions. The paper has shown that the high expectations on the transformative impacts of the new technologies are subject to heterogeneous effects on GDP growth. In fact, Industry 4.0 generates selective regional growth premium, in that where this transformation prevails and is more pervasive because of higher automation technology adoption, regional economic growth is higher. Differently, this is not the case for the digital service economy transformation, which shows no additional growth opportunities with respect to regions where transformations still lag behind. In fact, the strong competition between online and offline of service produces may dissipate local growth opportunities, an effect amplified by the disproportionate profits accrued by large digital intermediaries located elsewhere. Yet, pervasive digital technology adoption is associated with an increase in GDP growth rate, and such advantages accrue to all regions where adopters and users of digital technologies are located.

The results of the heterogeneous effects of the technological transformations are fully aligned with the smart specialisation strategy adopted by the European Commission for the past programming period, which claims that a 'one size fits all' policy is impossible to adjust to all regions. Policies are required to have a region-specific nature and to be tailored to the technological transformation profile of the region. Industry 4.0 reinforcing policies have to be structured around selective interventions dedicated especially to those regions experiencing the most advanced manufacturing transformation, since this is where the highest return on investments, in terms of growth, will manifest. Differently, the large-scale diffusion of digital technologies delivers growth advantages across all regions, regardless their prevailing transformation, thus contributing to smooth existing disparities and gaps. This is a desirable outcome that should receive adequate policy support everywhere, especially in lagging-behind transformation regions. The centrality of the digital transition in the frame of the NextGenerationEU plan, and its national applications through National Recovery and Resilience Plans (NRRP), now in the early implementation stages, is therefore supported by the results of the paper, which also raise some cautionary warnings about the potential impact of some of the industrial plans related to manufacturing transformation (e.g. Industria 4.0 in Italy or Industrie 4.0 in Germany and their analogous counterparts in other European countries). Digitalisation is confirmed as vital to sustain regional economic growth in all territorial (and transformation) settings; the path towards digitalisation however requires a complex mix of infrastructural upgrading, skills renewal and new skill creation, based on targeted training and educational strategies, up to regulatory framework condition to ensure widespread access to and fair competition in digital markets. All these aspects are key pillars of the NextGenerationEU plan, thus raising attention on and high expectations from the implementation of NRRPs.

With awareness of these cautionary remarks, from this work, one can conclude that 4.0 technological transformations are necessary in order for regions to achieve a smart growth, in alignment with the strategic goals of the Europe 2020 strategy to create value by anchoring economic growth to knowledge and technology creation and adoption (Chica-Olmo and Checa-Olivas 2021). Whether the new technologies are also able to push towards a socially and territorially cohesive growth, as foreseen in the frame of the NextGenerationEU plan, i.e. if they are able to reduce territorial disparities and to empower people, remains a compelling research and policy issue that we are committed to examine in our future research.

Notes

1. For the identification of 4.0 patents, see Laffi and Lenzi (2021) and Capello and Lenzi (2021c).
2. LQs have been computed by applying their well-known formula and have the usual interpretation, i.e. values greater than 1 indicate that a region is specialised in a specific sector (i.e. its share of employment in the sector is greater than the respective share in the EU) and vice versa.

3. In equations 1 and 2, u_r represents the random individual-specific error component and $\varepsilon_{r,t0}$ the region-specific time-varying error term.
4. https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2022, last visited 21/10/2022.
5. https://www.oecd.org/digital/ieconomy/, last visited 21/10/2022.
6. See endnote 6.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by European Observation Network for Territorial Development and Cohesion: [Grant Number ESPON T4 - Territorial Trends in Technological Transformations].

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Appendix

Table A1. Variables description and measurement.

Variables	Measurement	Years	Source
Variables used in the cluster exercise			
Sectoral specialisation			
Specialisation in technology manufacturing sectors	LQ on employment in technology manufacturing sectors*	Average 2008–2016	EUROSTAT
Specialisation in carrier manufacturing sectors	LQ on employment in carrier manufacturing sectors*		

(*Continued*)

Table A1. Continued.

Variables	Measurement	Years	Source
Specialisation in induced manufacturing sectors	LQ on employment in induced manufacturing sectors*		
Specialisation in technology services	LQ on employment in technology services*		
Specialisation in carrier services	LQ on employment in carrier sectors*		
Specialisation in induced services	LQ on employment in induced services*		
Variables used to describe regional transformation patterns			
Robot adoption			
Robot adoption in technology manufacturing sectors w.r.t. the European average	Number of robots in technology manufacturing sectors per 1000 employee in industry w.r.t. the European average	Average 2008–2016	IFR, EUROSTAT
Robot adoption in carrier sectors w.r.t. the European average	Number of robots in carrier manufacturing sectors per 1000 employee in industry w.r.t. the European average		
Robot adoption in induced manufacturing sectors w.r.t. the European average	Number of robots in induced manufacturing sectors per 1000 employee in industry w.r.t. the European average		
Digital technologies adoption			
Digitalisation intensity in technology services w.r.t. the European average	Share of firms selling online, at least 1% of turnover	Average 2009–2016	EUROSTAT
Digitalisation intensity in carrier services w.r.t. the European average	Share of firms selling online, at least 1% of turnover		
Digitalisation intensity in induced services w.r.t. the European average	Share of firms selling online, at least 1% of turnover		
Regional enabling conditions: patent intensity			
Patent intensity	Number of patents per 1000 inhabitants	Average 2010–2015	OECD-REGPAT, EUROSTAT
4.0 patent intensity	Number of 4.0 patents per 1000 inhabitants	Average 2010–2015	OECD-REGPAT, ORBIT EUROSTAT
Regional enabling conditions: education and entrepreneurship			
Education	Share of 25–64 age population with tertiary education attainment	Average 2013–2016	EUROSTAT
Innovation	Number of trademarks per 1000 inhabitants	Average 2010–2016	EUROSTAT
Regional entrepreneurship development index	Composite indicator*	2011	REDI
Regional enabling conditions: digital literacy			
Access to broadband	Share of population	Average 2013–2016	EUROSTAT
Daily use of Internet			
Use of social networks on the web			
Use of e-banking services			
Online purchase in the last month			
Online purchase: travel and holiday accommodation			
Personal wealth	GDP per capita	Average 2013–2016	EUROSTAT
Urbanisation	Share of population living in metropolitan areas		
Specialisation in the non-private sector	Location quotient on total employment**		
Employment in the manufacturing sector	Share of total employment		
Employment in the private service sector	Share of total employment		
High risk of automation**	Share of jobs at high risk of automation	2011	OECD-PIIAC and EUROSTAT; authors estimation

Note: * see the report website: https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/regional_entrepreneurship_development_index.pdf, last visited 2021/03/24
**For details see Capello and Lenzi (2021a).

Table A2. Mean values by cluster.

	1	2	3
	Digital service economy	Industry 4.0	
Number of regions	41	39	201
Variable used in the cluster exercise:			
Sectoral specialisation			
Specialisation in technology manufacturing sectors	0.55	2.47	0.67
Specialisation in carrier manufacturing sectors	0.6	1.62	0.91
Specialisation in induced manufacturing sectors	0.57	1.01	1.17
Specialisation in technology services	1.95	0.66	0.58
Specialisation in carrier services	1.2	0.86	0.92
Specialisation in induced services	1.15	0.84	1.02
Variables used to describe regional transformation patterns			
Robot adoption			
Robot adoption in technology manufacturing sectors	1.36	2.36	0.92
Robot adoption in carrier sectors	1.35	2.02	0.89
Robot adoption in induced manufacturing sectors	1.32	1.83	1.04
Digital technologies adoption			
Digitalisation intensity in technology services	1.18	1.62	1.36
Digitalisation intensity in carrier services	1.48	1.52	1.32
Digitalisation intensity in induced services	1.45	1.19	1.25
Regional enabling conditions: patent intensity			
Patent intensity	0.133	0.178	0.06
4.0 patent intensity	0.032	0.021	0.01
4.0 patent intensity in technology sectors	0.0059	0.0038	0.00
4.0 patent intensity in carrier sectors	0.0010	0.0010	0.00
4.0 patent intensity in induced sectors	0.0002	0.0001	0.00
Education	39.02	23.13	26.07
Innovation	0.348	0.156	0.09
Entrepreneurial attitude	48.68	45.42	44.68
Entrepreneurial ability	60.85	47.11	43.87
Entrepreneurial aspiration	59.13	50.73	45.84
Regional entrepreneurship development index	59.21	47.46	44.80
Access to broadband	86.01	81.77	76.89
Daily use of Internet	77.49	69.9	65.08
Use of social networks on the web	57.74	47.56	48.29
Use of e-banking services	57.73	49.23	44.75
Online purchase in the last month	54.33	47.31	40.73
Online purchase: travel and holiday accommodation	38.78	29.05	26.04
Personal wealth (GDP per capita)	46,258	29,889	24,330
Urbanisation	83.77	44.55	39.41
Specialisation in the non-private sector	0.97	0.9	1.08
Employment in the manufacturing sector	10.36	26.3	16.58
Employment in the private service sector	47.45	34.3	36.78
High risk of automation	12.95	16.61	17.47

Note: The ANOVA tests are all statistically significant at conventional levels (with $p < 0.05$).
Source: Adapted from Capello and Lenzi (2021b).