The digital service economy as a source of intraregional wage inequalities

Authors:

Roberta Capello, Camilla Lenzi & Elisa Panzera

Department of Architecture, Built Environment and Construction Engineering,

Politecnico Di Milano

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Abstract

The upsurge in wage inequalities is a common prediction in the literature analysing the labour market outcomes of the diffusion of traditional ICTs and advanced automation technologies. This issue, however, has never been explored in the case of advanced digital technologies affecting the creation and modes of provision of services, a phenomenon called digital service economy, which encompasses a sprawling range of businesses, mostly based on digital platforms, selling services, products or contents on on-line markets. The paper discusses conceptually whether and through which channels the different digital service economy value creation models can affect intraregional wage inequalities. Based on an analysis of 164 European regions in the period 2009-2016, the paper documents that only regions characterised by the most intense forms of digital service economy experience a rise of intraregional wage inequalities.

Keywords

Digital service economy, servitisation, product service economy, sharing economy, on-line service economy, regions, wage inequalities, Industry 4.0

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1. Introduction

The radical technological transformations that have been affecting businesses and society in the last few years have reignited the debate on the labour market consequences of the adoption of the new technologies. Many scholars and commentators, in fact, anticipate dramatic changes if not the risk of a generalised weakening and polarisation of job conditions and wages (Brynjolfsson & McAfee, 2014; Frey & Osborne, 2017).

Worries are not fully misplaced. In fact, the new technologies have the capacity to replace workers in a far wider spectrum of tasks, including non-routine ones, both manual and cognitive (Autor *et al.*, 2003). Depending on the estimation methods adopted, the literature proposes very different forecasts about the actual number of jobs at risk of displacement because of the adoption of the new technologies, ranging from gloomy outlooks (Frey and Osborne, 2017) to more optimistic scenarios (Nedelkoska & Quintini, 2018). Regardless the actual figures predicted, however, these results raise important warnings about the social and distributive consequences of the changes and compression of jobs, and consequently wages, due to the diffusion of the new technologies in businesses and society.

Importantly, the new technologies are expected to affect labour markets quantitatively and qualitatively. The displacement of workers can expand unemployment, up to pushing many out of the labour force. Job losses come together with an increasing redesign of the typology of jobs, frequently towards precarious, instant, service occupations, also known in the public debate and in the press as gig-jobs (Autor & Dorn, 2013). The casualisation of jobs, the deterioration of contract conditions and, in general, the increasing precariousness of work have been frequently highlighted as a likely consequence of the widespread diffusion of the new technologies (Rullani & Rullani, 2018). Moreover, the creation of gig-jobs goes in tandem with the creation of élite, high-skill ones, with a final mix likely in favour of gig-jobs compared to élite jobs (Autor & Dorn, 2013). All this can produce a generalised process of deskilling of the labour force and exacerbate the increase in wage inequalities and polarisation of employment, with the new technologies changing more and more the structure of labour demand and 'rising employment in the highest and lowest paid occupations.' (Autor, 2013, p. 185).

Moreover, wage inequalities among workers are reinforced by inequalities among firms. The differences between frontier and average firms are widening in most industries, with top firms earning superstar compensations and profit margins and business as usual activities struggling to survive (Andrews *et al.*, 2016). The amplification of the inequalities across firms can ultimately revert into the society with detrimental distributional consequences in terms of growing wage inequality and polarisation, stagnating median income and an aggregate overall declining aggregate labour share (Autor *et al.*, 2020). Put shortly, the diffusion of the new technologies presents a dual nature. Huge but highly unbalanced opportunities for new businesses jobs are opening, but likely to widen and to worsen existing inequalities among firms, among workers as well as between firms and workers.

Importantly, the present technological revolution shows a distinctive trait with respect to previous ones in that it relies on the co-existence and integration of multiple technologies, out of which intelligent automation and advanced digitalisation represent the dominant ones (Schwab, 2017).[1] However, by allowing for different business models and, thus, by entailing different sources of value creation and distribution, the new technologies can affect wage inequalities in different ways.

This heterogeneity of impacts on wage inequalities requires in our view, additional analysis. Great efforts, in fact, have been dedicated to the analysis of the impact of intelligent and advanced automation technologies on the displacement of manufacturing labour force and wage polarisation (see for examples Graetz & Michaels (2018); Dauth *et al.* (2021) for Germany, Humlum for Denmark (2019), Acemoglu *et al.* (2020) for France, Autor *et al.* (2020) for the US and OECD countries, Szalavetz for Hungary (2019).

The same attention, however, has not been dedicated, so far, to the impact of advanced digitalisation, intended as that bunch of technologies enabling the shift towards online markets as primary locus for market transactions, the key distinctive trait and novelty of modern digitalisation with respect to the past ICT revolution (Capello *et al.* 2022). In fact, most evidence comes either from studies on the adoption of digital technologies in the frame of the third industrial revolution, i.e. ICT equipment and infrastructure (Autor *et al.*, 2003; Autor & Dorn, 2013) or from (quantitative) firm or platform case studies (Drahokoupil & Piasna, 2017).

This relative paucity of studies is particularly undesirable for two main reasons. First, the adoption of the new digital technologies affects the creation and mode of provision of services, enabling the rise of a large variety of value creation models, a multifaceted phenomenon called in this paper digital service economy. Specifically, the digital service economy comprises a sprawling range of businesses mostly based on digital platforms ultimately redesigning the

[1] In this paper, intelligent automation technologies refer to last generation robot technologies merging robotics and artificial intelligence (McAfee & Brynjolfsson, 2017). Advanced digitalisation, instead, refers to the use of digital technologies for business purposes and enabling companies to operate online markets (Capello *et al.*, 2022).

boundaries of products towards services (Capello & Lenzi, 2021; Capello *et al.*, 2022). Importantly, depending on the specific digital service economy value creation model considered, different impacts on wage inequalities can be expected.

Second, the digital service economy, in most of its value creation models, is mainly an urban phenomenon. Cities, in fact, are characterised by a heterogeneous demand with a vast variety of tastes and a cultural openness to technological advances, thus allowing for a large market for online services. At the same time, cities host a large labour market, with a variety of occupations and skills. Last, but not least, large cities are the loci of creativity and entrepreneurial spirit, which feed the capacity to exploit the new technological opportunities offered by these technologies. For these reasons, the contradictions and inequalities generated by the adoption of the new technologies are expected to concentrate mainly within regions hosting large urban areas.

However, the transformation induced by the adoption of the new technologies and by the growing role of the digital platforms is not limited to the urban areas. The effects are not to be expected homogeneous among different areas as they are not exposed, with the same intensity, to the changes induced by the digital service economy. Each area is in fact expected to have a prevailing value creation model - or a combination of value creation models - that explains the aggregate effects on the local labour market.

This paper aims at addressing both issues by proposing an analysis of the impact of different digital service economy value creation models on intraregional wage inequalities. On conceptual grounds, the paper enriches existing literature by elaborating on the relationships between different types (and combinations) of digital service economy value creation models and wage inequalities. Empirically, based on an innovative data set covering 164 EU regions in the period 2009-2016, the paper highlights which types (and combination) of digital service economy value creation models are associated with the highest wage disparities and in which regions these detrimental effects can be expected the most.

The remainder of the paper is organised as follows. After presenting the different archetypal digital service economy value creation models, the paper elaborates on their potential expected impacts on wage inequalities (Section 2). The methodology to identify the different digital service economy value creation models and their geography in EU regions are presented in Section 3, while Section 4 describes the data and econometric approach used to assess the impact of the different identified value creation models on wage inequalities. Results are discussed in Section 5 and conclusive remarks are proposed in Section 6.

2. Digital service economy value creation models and wage inequalities: conceptual expectations

The rapid diffusion of advanced digital technologies, largely pioneered by platforms managing on-line markets for the exchange of services, products or contents, is radically changing and expanding the modes of service creation and provision. Importantly, these changes imply a continuous redesign of the boundaries between products and services in favour of the latter, enabled by the increasing dematerialisation or unbundling of products (e.g. a car) from the service they may provide (e.g. a ride).

In this work, we define this phenomenon as digital service economy meant as an economy encompassing a sprawling range of businesses, mostly based on digital platforms, which sell services, products or contents on on-line markets (Capello *et al.*, 2022). Digital platforms replace bilateral with trilateral relationships, involving a producer (a worker, a content producer, a service producer), a requester, and the platform (Koutsimpogiorgos *et al.*, 2020). A digital platform can therefore be defined as a 'matchmaker' between producers who offer a production capacity and recipients interested to use, buy, or enjoy it (Kornberger *et al.*, 2017).

The digital service economy encompasses several value creation models, each characterised by distinctive sources of value created online, different distribution of value among the actors involved in online transactions and therefore different positive and negative effects on the economy and the labour markets.

A way to distinguish digital service economy value creation models is through the identification of the different players involved and the distinct sources of value creation and distribution (Capello *et al.*, 2022). Specifically, digital platforms can perform their role of 'matchmaking' in different ways, according to their pervasiveness in the market transactions. In their simplest form, they can purely serve as a technical basis to generate digital value chains involving suppliers and customers. However, they can also facilitate transactions by easing the matching of buyers and sellers needs. In more complex forms, they can enrich the role of pure intermediaries by selling their own services and products competing with those offered by the providers hosted on the platform itself. In the same vein, producers of the service, goods or contents offered can be manufacturing firms, as well as an owner of a resource with idle capacity, or of spare time.

The first type of digital service economy value creation model is the so-called product-service economy, which refers to the original definition of servitisation introduced in the 1980s (Vandermerwe & Rada, 1988). Servitisation is a strategy put in place by manufacturing firms to offer services together with the product (see for reviews Rabetino *et al.*, 2021 and Baines *et al.*, 2017 on servitisation; Baines *et al.* (2007) on product-service systems). In fact, traditional manufacturing companies externalise services, which are typically provided by distributors or specialist service providers. Differently, fully servitised manufacturing companies adopting service-based business models, offer physical products as services, e.g. customers subscribe to a long-term contract and pays for use, performance, or availability of this resource. Companies can also provide mixed offerings like advanced product-service systems (PSS) (Rabetino *et al.* 2021).

Through servitisation, manufacturers redesign their business models from product-only offers to service-oriented offers, shifting the business perspective from a product-based business model to a demand-oriented one (Müller *et al.*, 2018). The joint provision of products and services, i.e. product-service systems, enables more targeted offers and enlarges the range of potential customers up to filling new market niches. Consequently, firms can expand their market size as well as their market share over competitors (De Propris & Storai, 2019; Van Oort & Thissen, 2021). Servitisation has been richly studied by scholars that largely documented the shift in manufacturing business models towards the offering of bundles of products and (digital) services turning into a symbiotic recoupling between manufacturing and service activities centred on product-service innovation (Rabetino *et al.* 2021; 2018; 2017; Gebauer *et al.* 2021; Kohtamaki *et al.* 2021a). Digitalisation is boosting and enriching this traditional idea of servitisation, although the transition to digital servitisation is not automatic nor simple (Opazo-Basáez *et al.*, 2022; Gebauer *et al.*, 2021; Kohtamäki *et al.*, 2019, 2020, 2021). Specifically, digital servitisation refers to the deployment of digital technologies to create and seize value from product-service offerings, i.e. value creation stems from the supply of tangible products supported by additional digital or digitally-enabled services, such as on-line support and remote monitoring (Tiang *et al.*, 2022). In this respect, digital platforms can facilitate this transition by improving relationships with customers (front-end platforms) as well as with suppliers (back-end platforms), and manufacturers may rely on outsourced platforms as well as develop their own ones up to provide platforms as a service (Eloranta & Turunen, 2016; Kohtamäki *et al.*, 2019; Cenamor *et al.*, 2020). Moreover, the progressive evolution and embeddedness of digitalisation within firms led also to a substantial transformation of the products themselves that become smart, intelligent and connected resulting in radical changes in companies internal structures and organisations as well as in competition mechanisms (Porter & Hepplemann, 2014; 2015).

As well documented by the literature, digital servitisation and the product service economy are not the only ways in which digitalisation and technological change do interest manufacturing companies. In fact, Industry 4.0, also called the *smart fabric* (Xu *et al.*, 2018), started to develop within the manufacturing firms enabled by the spread of new technologies such as artificial intelligence, Internet of Things, robotics and nanotechnologies, just to mention a few (Brynjolfsson & McAfee, 2014; Schwab, 2017; Capello & Lenzi, 2021). The traditional manufacturing industry business models and internal processes have been increasingly revolutionised by digitalisation and robotisation. Automation of production systems, improved interconnections with suppliers, customers and business partners, increasingly integrated physical products through information networks are all innovations related with Industry 4.0 transformations. This robotisation and automation processes within the manufacturing context backdate the product service economy as it has already started in mid-1980s. Consequently, a rich and well-developed literature has studied Industry 4.0 both in terms of its peculiar characteristics and with respect to its potential and actual consequences on the labour market. As explained by Müller *et al.* (2018), three main characteristics are encompassed in the Industry 4.0 phenomenon: high-grade digitalisation of all phases of the production process; smart manufacturing through cyber-physical systems resulting in self-controlled production systems; inter-company connectivity between suppliers and customers within the value chain (Lasi *et al.*, 2014). Associated with these transformations, uncertainties and concerns related to job replacements and displacements began to arise. Determining and assessing the effects of Industry 4.0 on job dynamics and wage polarisation is neither unequivocal nor straightforward. In fact, different and opposite effects might arise and combine, sum up, or balance out. On the one hand, displacement effects might hit low-skilled and manual workers that could be replaced by advanced machineries and robots (Autor *et al.*, 2003; OECD, 2018). On the other hand, higher productivity of manufacturing firms led by increased automation and efficiency could be linked with increased labour demand (Autor & Dorn, 2013; Dauth *et al.*, 2021) and creation of new high-skilled jobs.

Similarly, the potential impacts of the product service economy on wage inequalities are controversial and difficult to assess. In fact, these radical changes require manufacturing firms acquire competences that would naturally reside outside a manufacturing production process, e.g. customised design, repair and maintenance, consultancy of different kinds. These competences can be acquired and/or developed within the servitised manufacturing firm or sourced from local service providers. A rich strand of the literature studies these local relationships between manufacturing companies and knowledge-intensive business services (KIBS) from a territorial perspective under the label of territorial servitisation or local product-service innovation systems (see for instance De Propris & Bailey, 2020; Barzotto *et al.* 2019; Vaillant *et al.*, 2021; Sisti & Goena, 2020; Gomes *et al.*, 2019; Lafuente *et al.* 2019; Sforzi & Boix, 2019; Vendrell-Herrero & Bustinza, 2020).

The need for new competences may support not only a business refocusing but also a reorientation if not an upgrade of workers profile towards jobs requiring higher educational attainment and skill level, various and more complex cognitive and abstract tasks, and, thus, higher wages (Dauth *et al.*, 2021). Possibly, these new tasks can lead to the creation of new élite jobs and, more generally, to an increase in the number and quality of jobs achievable both by draining talents from competing local service firms as well as by pushing local business partners to upgrade (De Propris & Storai, 2019). At the same time, the radical refocusing of business activities and a reorientation of the tasks content of jobs away from intensive routine manual tasks may lead to a reduction of low-skill jobs, the ones characterised by the most intensive routine manual tasks.

However, the magnitude of the overall effects on labour markets can be limited by the extent of servitisation processes within existing manufacturing firms. Estimates for European countries indicate that the share of servitised manufacturing firms vary in a range from 3% to 10% in European countries (Vendrell-Herrero & Bustinza, 2020).

This limited diffusion may significantly constraint the impact of such value creation models on intraregional wage inequalities, with impacts mainly affecting single firms or their local service providers. Overall, the impact of this form of digital service economy on intraregional wage inequalities is expected to be modest and mostly dependent on an increase of top wages, associated with the upgraded jobs and tasks, rather than with a decrease of bottom ones.

The second value creation model refers to the so-called sharing economy. Specifically, in this work, the label sharing economy is associated with the creation of new online markets for under-utilised assets or idle resources (e.g. a spare seat in a car, a spare bedroom, spare time) which are made temporarily accessible to other users upon payment, on the basis of a peer-to-peer exchange. The owner of the resource can exchange its excess capacity, which in an offline situation would have had no value (Frenken & Schor, 2017). The sharing economy generally involves trilateral transactions, characterised by the exchange of products, services or contents through digital intermediaries (Schor, 2016).

In this case, two main effects can be expected. First, and common to all digital service economy value creation models based on intermediary platforms, high-skill, élite jobs can be created by the intermediary platforms. In most cases, platform owners are superstar firms, with fast increasing profits despite a limited number of employees (i.e. the so-called business model of mass without scale). Superstar firms may create high-skill, élite jobs (e.g. managers or executives as well engineers) for their headquarters and research facilities. This effect, however, is very limited in number, and highly concentrated in those few (mostly non-European) regions hosting such activities. Such a small number is insufficient to substantially affect the overall regional employment level and, consequently, wage inequalities. On the other hand, a displacement effect can take place, hitting on low-skill workers. In fact, the provision of customer-to-customer services can enhance competition with traditional offline businesses (e.g. BlaBlaCar versus traditional transport services), and can erode their market share. The contraction of business opportunities can lead to a displacement of workers employed in those activities and, indirectly, to a reduction of their wage conditions (Rullani & Rullani, 2018; Frenken & Schor, 2017). The gravity of such contraction is unclear given the uncertainty of the overall weight on the economy of the substitution between off-line and online businesses. The overall impact of the sharing economy on intraregional wage inequalities, then, is expected to be driven by the negative effects generated on traditional offline businesses and their employees, worsening intraregional wage inequalities.

Finally, the so-called online service economy represents the most complex form of digital service economy value creation model in which digital platforms provide services and products (e.g. mobility solutions, food and beverage services, payment systems) without owning the assets necessary to produce and/or deliver such services or goods. Importantly, the online service economy rests on the dematerialisation of assets or products enabled by the unbundling of products from the service a product can offer, thus enabling an important shift from purchasing goods to using goods and paying for the utilisation, the function or the utility consumers may extract from the product, e.g. by renting or leasing it. In the case of Uber, the asset (a car) is unbundled from the service it may provide (a ride), i.e. it is dematerialised into a service (a ride), and the intermediate service becomes the primary source of value creation. On their turn, digital platforms provide goods, services or contents, without owing the assets. Uber does not possess a fleet of cars, as much as Foodora or Justeat operate without having restaurant facilities or Stripe is active without owning nor managing any payment system. What intermediaries own is the data on suppliers and customers, enabling them to match demand and supply rapidly with low transaction and search costs.

Differently from the previous cases, in the case of the online service economy, platforms enable new business and job opportunities, thus deeply affecting labour markets in terms of employment level and wage inequalities. The online service economy business model, in fact, relies frequently on on-call contingent workers, using their own tools and equipment to perform the productive work associated with the supplied service (Stanford, 2017). Service providers (e.g. Uber drivers or Deliveroo riders) are often 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. These workers are commonly known in the literature and in the press as gig workers.

The online service economy value creation model is, however, feared for different reasons, primarily for the creation of an unequal income distribution, in favour of digital platforms and for inducing a fierce competition between online and off-line activities (Rahman & Thelen, 2019). Record majors, publishing and printing companies are examples of businesses put under severe competition by online platforms, whose digital contents replace traditional products (e.g. CD and physical books). Moreover, digital platforms that create on-demand work open to huge problems in terms of low pay, quality and stability of new jobs created.

Therefore, three main effects can be expected as a consequence of the diffusion of the online service economy value creation model. Two are common to the sharing economy, i.e. an increase in high-skill, cognitive, élite jobs and their wages, mostly linked to intermediary platforms, and more marked shadow effects on traditional offline workers at risk of being displaced or at least suffering a downward pressure on wages. While the first effect is not geographically identifiable, the second one takes place in the area where online services are consumed. More important, however, is the third effect, related to the expansion of local low-skill, low-paid and unsecure jobs. Taken together, these effects lead to expect a worsening of intraregional wage inequalities in the case of the online service economy value creation model.

Table 1 summarises the key characteristics of each digital service economy value creation model and its expected impacts on intraregional wage inequalities.

Table 1. Digital service economy: effects on business activities, local labour market and expectations on intra-regional wage differentials

	Effects of digitalisation on business activities	Impact on the local labour market	Expectations on intra-regional wage differentials
Product service economy	New activities like customised design, repair and maintenance, consultancy of different kinds.	Jobs requiring higher educational attainment and skill level, with a reorientation of the tasks content of jobs away from intensive routine manual tasks	Modest effect, mostly dependent on an increase of top wages, rather than with a decrease of bottom ones
Sharing economy	Creation of new online markets for under-utilised assets or idle resources	Creation of high-skill, élite jobs by the intermediary platforms Displacement of low-skill workers due to crowing out effects on traditional offline businesses	Sharing economy
Online service economy	Creation of new online markets for dematerialised products. From purchasing goods to paying for the utilisation, the function or the utility of the content	New job opportunities, especially for on-call contingent workers. Increase in high-skill, cognitive, élite jobs and their wages, mostly linked to intermediary platforms.	Online service economy

The next section details the operational strategy applied to identify these different digital service value creation models in European regions.

3. Digital service economy value creation models and regional patterns in Europe

3.1. The identification of digital service economy value creation models in European regions

The multifaceted nature of digital service economy value creation models makes extremely difficult the mapping of their spatial distribution. The very nature of digital platforms makes substantially impossible to identify their specific location. Following a previous work by the authors (Capello *et al.*, 2022), this limit can be overcome by reasoning on the more traditional players (i.e. producers and recipients) involved in the different digital service economy value creation models, whose location is easily identifiable and their transition to online markets measured through their intensity of adoption of digital technologies. Regions characterised by a greater presence of these actors and by a greater technology diffusion are those best positioned to host each of the different digital service economy value creation models. Empirically, the latter can be distinguished, on the basis of the regional sectoral specialisation and adoption of digital technologies in different specific and representative sectors, as detailed below. In fact, the specialisation of a region in each of these sectors does not guarantee the presence of a digital transition per se but can spur it when adoption of digital technologies in those specific sectors is particularly high. Therefore, sectoral specialisation and adoption intensity shall be considered jointly. In details:

- Manufacturing has been chosen as the main sector involved in the product service economy. Regions with a stronger manufacturing profile and with a higher presence of manufacturing firms prone to switch to the new service-based business model are expected to represent the best setting for the product service economy. In fact, the higher the pervasiveness of manufacturing activities in a region, the higher the probability to shift towards the new value creation model and to develop new technology-led services within the sector. Moreover, the regional share of online sales in the manufacturing sector has been used to measure the intensity of adoption and to account for capacity of delivering additional services to users. Furthermore, even though the present work focuses on the digital service economy value creation models, it is likely that, in the specific case of the manufacturing sector, this phenomenon is simultaneously occurring with Industry 4.0. Therefore, a combination of product service economy and Industry 4.0 is also taken into consideration for a more complete analysis of the joint phenomena occurring in the manufacturing context.

- Food and beverage service activities and retail are considered as the most representative sectors in which the online service economy can take place. More specifically, the food and beverage sector represents an online service economy value creation model with a short range delivery system whilst retail best represents online service economy value creation models with potential long range delivery systems. The latter can produce disruptive effects on off-line activities, both local and extra-regional ones, whereas the former stimulates competition only between online and offline local activities. Specifically, the online service economy value creation model has been identified by looking at the regional specialisation and the regional share of online sales in each of the two sectors.[2] The distinction between short range and long range delivery services is meant to capture the idea that, hypothetically, by their own nature specific services can be sold everywhere (e.g. retail) while other have a predominant local dimension (e.g. food and beverage services). Even though also in the retail sector most businesses have a local dimension and demand, in principle, going online could help local retailers gaining very distant, if not global, markets. On the other hand, going online in the food and beverage service sector does not necessarily make service providers (and not the intermediary platforms) reaching distant markets.

Importantly, by crossing the regional sectoral specialisation with the regional sectoral adoption intensity dimensions, four alternative situations can be conceptually conceived and empirically detected, each being characterised by an increasing degree of diffusion of a specific value creation model (Figure 1):

- absence of a specific digital service economy value creation model, when both regional sectoral adoption intensity and sectoral specialisation are below the national mean;
- potential digital service economy value creation model, when regional sectoral adoption intensity is below the national mean in sectors of specialisation;

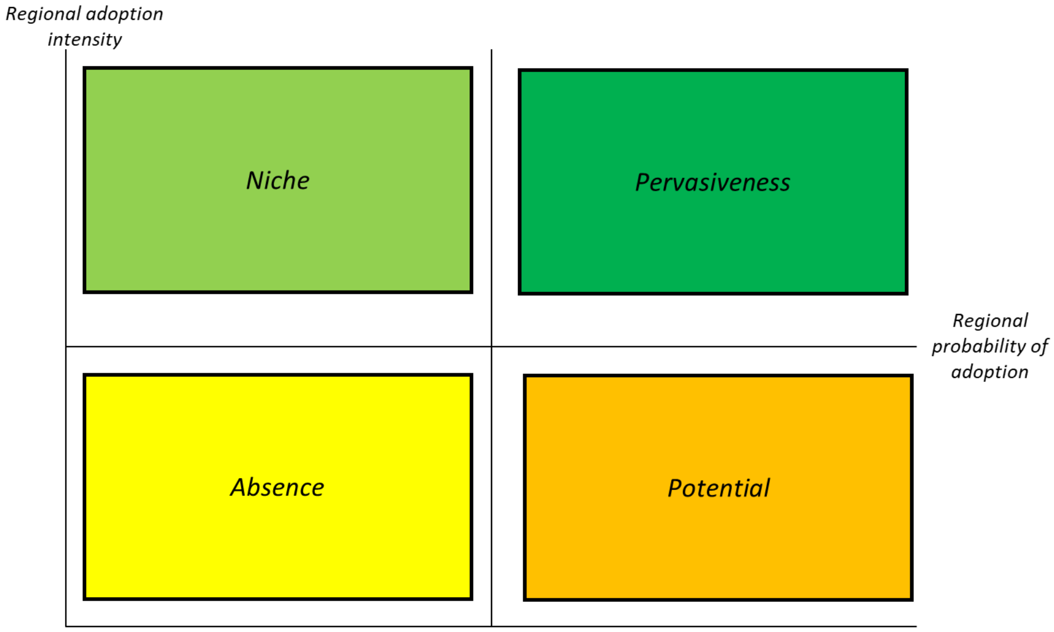
[2] Note that the indicator of online sales captures the extent to which specific sectors of economic activities are able to make the transition towards online markets, mostly managed by intermediary platforms. The choice of the sectors to be examined has not been implemented on the basis of the fact that companies active in specific sectors operate fully online but on the expectation that the transition to online markets is mediated by the operation of platforms and can affect the dynamics of offline and online competition, with detrimental effects especially for those offline activities characterised by a very local dimension.

- niche digital service economy value creation model, when adoption intensity is high in sectors that are not those of specialisation;
- pervasive digital service economy value creation model, when both indicators are above the national average.

For what concerns the sharing economy, the regional adoption is measured through the share of population exchanging goods and services online. The diffusion of digital technologies in the local population instead accounts for the probability of the phenomenon and is measured with the regional share of population using internet daily. Crossing the two indicators, the same four situations highlighted above (and presented in Figure 1) arise.

Table 1 summarises the indicators used to measure the regional probability of adoption and the regional adoption intensity for the three identified digital service value creation models.[3]

Figure 1. Development stages of value creation models in the digital service economy



Source: Capello *et al.* 2022

The data used for the computation of these indicators - standardised with respect to the national values to mitigate strong country effects -[4] have been sourced from Eurostat. Specifi-

[3] We are aware that in some regions these sectors account for a low fraction of regional GDP and employment, whereas we look at the overall wage distribution and inequalities. This aspect is considered in the econometric exercise by controlling for the respective regional sectoral employment share.
[4] This choice leads to exclude from the analysis those countries composed of a single NUTS2 region (i.e., Malta, Luxembourg, Cyprus, Estonia, Latvia). Standardisation with respect to the national value has the goal to take into account strong national differences in digital infrastructure and sectoral composition.

cally, regional sectoral specialisation in the different sectors is analysed based on EUROSTAT Structural Business Statistics. Data on regional intensity of online sales (i.e. the regional share of firms with at least 1% of turnover from online sales) is sourced from EUROSTAT at the sectoral national level, next apportioned at the regional level.[5]

The reference year for the variables (i.e., probability and intensity of adoption) used to compute the four classification variables indicating the development stage of each specific digital service economy value creation model is 2010.

Table 2. Value creation models in the digital service economy and their respective indicators

Value creation models	Probability of adoption	Adoption intensity
Product service economy	Regional location quotient in manufacturing (sector C)	Regional on-line sales in manufacturing with respect to the country
Sharing economy	Regional share of population using internet with respect to the country share	Regional share of consumer-to-consumer exchange of goods and services online with respect to the country
On-line service economy	Regional location quotient in food and beverage service activities (sector I56)	Regional on-line sales in food and beverage service activities with respect to the country
	Regional location quotient in retail (sector G)	Regional on-line sales in retail with respect to the country

Source: Capello *et al.* 2022

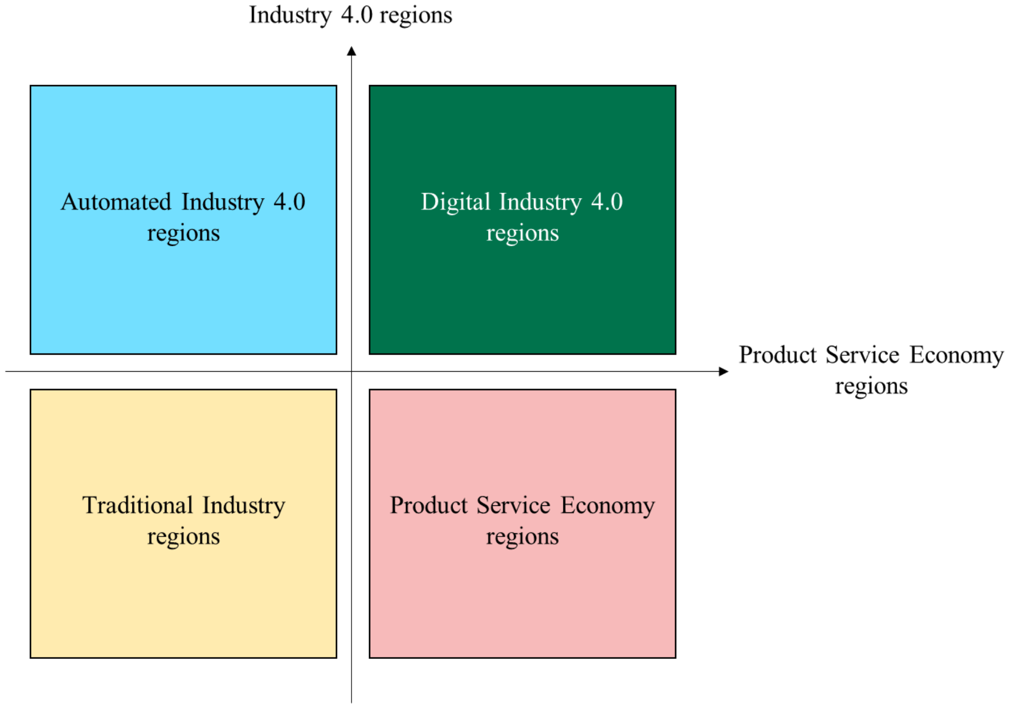
As previously mentioned, the product service economy value creation model might coexist with the Industry 4.0 transformation; in some cases, the product service economy and Industry 4.0 are equated (De Propris & Bailey, 2020). Combining the taxonomy proposed in this work with an Industry 4.0 measurement proposed by the authors in a previous work (see Capello & Lenzi, 2021),[6] a complete classification of the manufacturing context is here presented. The following

[5] More specifically, the regional online sales have been obtained by apportioning the national value according to two weights: the share of population with internet access and the regional sectoral weight (see the Appendix (A1) for full details on the computation of the online sales indicator).

[6] The identification of Industry 4.0 regions has been developed using two dimensions: regional specialisation and regional adoption in two main sectoral groups, i.e. technology and carrier sectors. Regional specialisation has been measured using NACE 2-digit level data obtained from SBS (Structural Business Statistics) available from EUROSTAT in the 2008-2016 period. Employment in the technology sector has been obtained by summing up employment in each of NACE 2-digit level sector defined as technology sector (i.e., Manufacture of wood and paper products and printing, furniture (16-17-18-31); Manufacture of computer, electronic and optical products (C26); Manufacture of electrical equipment (C27); Manufacture of machinery and equipment (C28); Manufacture of transport equipment (C29-30); Other manufacturing, repairs of computer (C32-33)). Regional sectoral adoption has been measured using robot penetration. National data on robot adoption has been obtained from the International Robot Federation (IFR) and subsequently apportioned at the regional (NUTS2) and sectoral level (for more details, see Capello and Lenzi (2021)).

figure (Figure 2) presents the four possible situations that could characterise regions according to the presence or absence of the two phenomena.

Figure 2. Typology of Industry 4.0 regions



The first category refers to *traditional industry* regions. These regions are specialised in the manufacturing sector without presenting any specificities neither in terms of Industry 4.0 (i.e., automation) nor in terms of the product service economy (i.e., digitalisation). *Product service economy* regions are instead characterised by a pervasive product service economy value creation model without however being interested by the Industry 4.0 phenomenon. *Automated Industry 4.0* regions, on the contrary, presents a predominance of Industry 4.0 not combined with pervasiveness of product service economy. Finally, *digital industry 4.0* regions present a profile characterised by pervasiveness of both Industry 4.0 and product service economy. A map of the spatial distribution of these categories across European regions can be found in Appendix A2.[7]

[7] The digital industry 4.0 therefore represents a more restrictive definition of the product service economy, based on the combination of digitalisation and automation. Empirically, therefore, the digital industry 4.0 represents a subsample of the regions characterised by a pervasive or potential product service economy. This classification excludes all regions that do not show any specialisation in manufacturing, i.e., regions in which the product service economy is absent or niche.

3.2. Digital service economy patterns in European regions

Notwithstanding the importance of investigating the presence and the specific effects of each digital service economy value creation model, the different value creation models may coexist in regional economies and combine heterogeneously across space. Therefore, the specific and distinct effects that the product service economy, the sharing economy and the online service economy might have in affecting intraregional wage inequalities could sum up, combine or balance out whenever different digital service economy value creation models are simultaneously present in a region.

In order to identify the prevailing digital service economy value creation model in a region, the classification variables representing the four development stages (described in the previous section) for each of the three digital service economy value creation model have been considered as the inputs of a k-means cluster analysis. By this analysis, European regions have been grouped according to their predominant digital service economy value creation model, i.e. the one which is, in relative terms, more important in profiling and describing each region. Based on this cluster analysis, five digital service economy patterns have been identified, each characterised by different mix and intensity of development (i.e. development stages) of the five digital service economy value creation models (Figure 3):

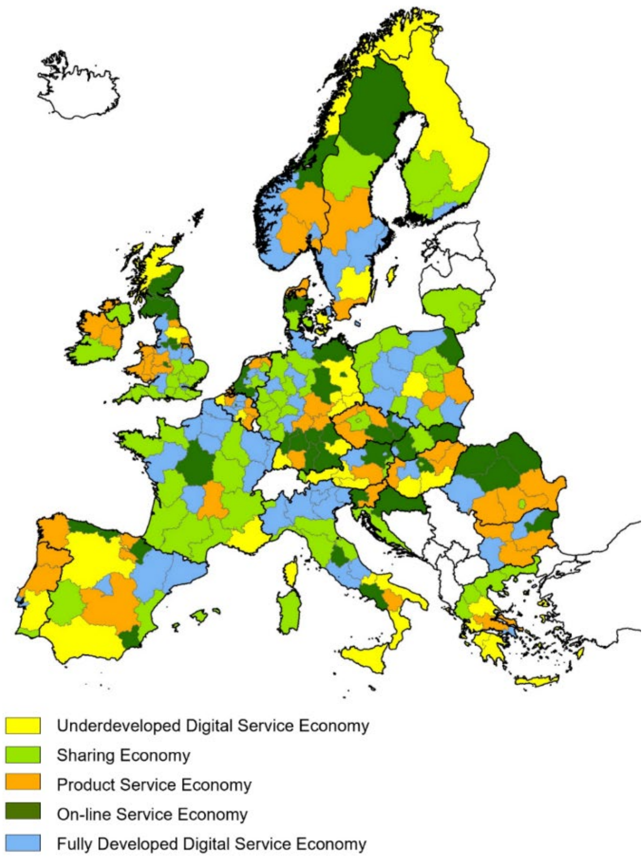
1. underdeveloped digital service economy: regions in this cluster are characterised by the lack of any digital service economy value creation model and are generally weak regions from the technological and economic point of view;
2. sharing economy: regions in this cluster exhibit a pervasive sharing economy. Other digital service economy value creation models are instead less developed and remain either potential or absent;
3. product-service economy: regions in this cluster predominantly show a strong industrial profile and are characterised by a manufacturing servitisation value creation model either pervasive or potential. A remarkable trait of this cluster is the absence of all the other types of value creation models;[8]
4. online service economy: regions in this cluster show a pervasiveness of the online service economy value creation model in both its forms, i.e. with short- and long range delivery systems;

[8] Only few regions in this group are characterised by an automated industry 4.0 or a digitalised industry 4.0 (see Figure 3 and Figure A2.1), suggesting that the industry 4.0 transformation mainly co-locate with more complex forms of digital transformation, e.g. the fully developed digital service economy.

5. fully developed digital service economy: regions in this cluster score high in terms of all digital service economy value creation models and are characterised by a favourable environment to technology adoption and use in businesses and society.

Details on the predominant digital service economy value creation model in each specific pattern as well as the key characteristics and the socio-economic profile of the five groups of regions are available in Tables A3 and A4 in Appendix.

Figure 3. Digital service economy patterns in Europe



4. Data and econometric approach

4.1. The dependent variable

In order to empirically investigate and test the potential impacts of the different digital service economy value creation models and their spatial combinations on intraregional wage inequalities, we used data from the Compnet (The Competitiveness Research Network) database. Originally founded by the European System of Central Banks in 2012, CompNet provides a micro-founded data set covering productivity indicators for 20 European countries, including a series of labour market related indicators available at NUTS 2 level and harmonised to allow cross-country comparability.[9]

A major advantage of CompNet's data set with respect to alternative sources (e.g. EU-SILC, EU-LFS) lies in the provision of detailed information for each indicator, including its distribution, an aspect particularly relevant to obtain a measure of wage inequalities, at the NUTS 2 level. Specifically, intraregional wage inequalities are measured as the difference between the 90th percentile and the median of the labour cost per employee within each region in the period 2009-2016.[10] This indicator offers information on the gap between the highest paid and the median paid occupations within each region and is therefore a suitable indicator for our analysis. Ideally, it would have been preferable to consider the gap between the bottom (e.g. 10th percentile) and the top (e.g. 90th percentile) of the distribution, as common in the literature discussing the role of technology on job polarisation, meant as the exacerbated distance between well-paid skilled jobs and low-paid least-skilled ones. Unfortunately, data unavailability prevented us to follow this direction. In the attempt of mitigating this issue, we subtracted from the 90th percentile the median value of the distribution, which suffer less than the mean value from the presence of particularly high or low values in the wage distribution. Even if this indicator cannot be directly interpreted as a measure of job polarisation, it is still able to account for wage dispersion and thus inequalities. The geography of this variable is displayed in Figure 4

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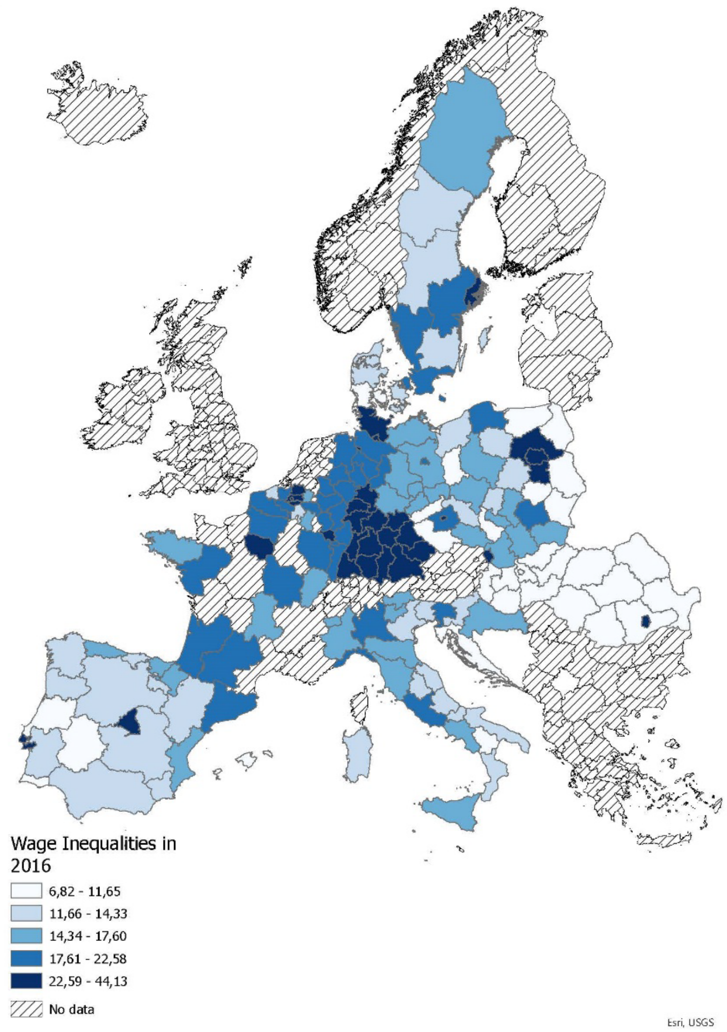
[9] A few countries present missing data for some variables, including the ones of interest in this analysis, e.g. France. The presence of missing countries and of selected regions is unfortunately a limitation of the present study. This limitation however is more than compensated by the rich details on each variable distribution available in CompNet and unavailable from other sources, as described below.

[10] Differently from other papers, we used the median value instead of the 10th percentile value to compute the inequality indicator because of data constraints. In particular, 10th percentile data are missing for Denmark, Germany, Portugal and Hungary. Moreover, we preferred to use the difference between the top and the median wages rather than their ratio as to be able to take the levels of the variable into account.

whilst the geographical distributions of the median and the 90th percentile for the start and end of the period of analysis are shown in the Appendix (Figure A5.1 to A5.5 respectively).

Notwithstanding strong national effects, there are important regional differences in terms of median labour cost, particularly evident in the case of Italy, Spain and Germany (Figure A5.1); this geography is relatively stable over time, even if in presence of general upward trend (Figure A5.2). Regional differences become more marked when looking at top wages (i.e. the 90th percentile of labour cost, both in 2008 and 2016, displayed in Figures A5.3 and A5.4, respectively). In particular, capital regions persistently show the highest labour cost in all countries, with the exception of Italy and Germany. This effect is particularly evident in the case of Eastern countries, which present in general lower median labour costs. Persistency characterises also the geography of wage inequalities, as highlighted by the comparison between Figure 4 and Figure A5.5.

Figure 4. Intraregional wage inequalities in European regions, 2016



4.2. The econometric framework

On econometric grounds, in order to estimate the impact of the different digital service economy value creation models and their spatial combinations on intraregional wage inequalities, we estimated the following stylised equations:

$$Wage\ Inequalities_{r,t} = \alpha + \beta_1 digital\ service\ economy\ value\ creation\ model_{r,k} + \beta_2 X_{r,t-1} + \beta_3 country\ fixed\ effects + \beta_4 time\ fixed\ effects + \beta_5 country * time\ fixed\ effects + \alpha_r + \varepsilon_{r,t} \quad (1)$$

$$Wage\ Inequalities_{r,t} = \alpha + \beta_1 digital\ service\ economy\ patterns_r + \beta_2 X_{r,t-1} + \beta_3 country\ fixed\ effects + \beta_4 time\ fixed\ effects + \beta_5 country * time\ fixed\ effects + \alpha_r + \varepsilon_{r,t} \quad (2)$$

where wage inequalities in region r and at time t are made dependent on a series of regional level determinants $X_{r,t-1}$, α_r the random individual-specific error component and a region-specific time-varying error term $\varepsilon_{r,t}$. The period considered is the 2009-2016 one and the regions considered are 164 NUTS 2 regions.

The key explanatory variable in equation (1) is $digital\ service\ economy\ value\ creation\ model_{r,k}$, with k accounting for the pervasive stage of each of the four digital service economy value creation model. Specifically, four dummy variables have been introduced, taking value 1 if in a region a specific value creation model has a pervasive development stage and 0 otherwise.[11] As noted in Section 3.1, the four dummy variables have been measured for 2010. While a reasonable time lag has been considered in the econometric analysis, thus avoiding simultaneity bias, we cannot exclude some remaining, though minor, risks, of reverse causality. To be fully exhaustive, the same specification has been tested including a dummy variable indicating digital industry 4.0 regions.

[11] Notice that the four dummy variables originate from four different categorical variables (corresponding to the development stages of each digital service economy value creation model). More in detail, the four categorical variables range from 1 to 4 accounting respectively for absence, potential, niche or pervasiveness (see Figure 1). A dummy variable has been then created for each digital service economy value creation model taking the value of 1 if the value creation model is pervasive and 0 otherwise. An additional variable dummy variable has been created to flag digital industry 4.0 regions as to test the specific role of this more restrictive definition and measurement of the Product service economy. The dummy variables for each value creation model have been introduced separately to mitigate multicollinearity concerns given the fact that different digital service economy value creation models might co-exist in the same region. In a separate specification we simultaneously included all the value creation models as a robustness check.

The key explanatory variable in equation (2) instead is $digital\ service\ economy\ patterns_r$, which aims at capturing the effect of the coexistence of different digital service economy value creation models in their mutual combinations as identified through the cluster analysis. A set of five dummy variables has been introduced, with each dummy accounting for one of the five digital service economy patterns characterising each European region i.e., underdeveloped digital service economy, sharing economy, product service economy, online service economy, fully developed digital service economy, being underdeveloped digital service economy the reference case.

In line with existing literature in the field (e.g. Acemoglu & Restrepo, 2020; Dauth *et al.*, 2021), beside country and year fixed effects as well as their mutual interaction terms, a set of control variables $X_{r,t-1}$ measured at NUTS 2 level is included in both equations (1) and (2), namely

- the median age of the population;
- the female share and the foreign share of active population, as both categories of workers might be characterised by lower average wages;
- human capital, as tertiary educated workers generally enjoy higher wages;
- the risk of job automation, as labour markets characterised by high percentage of replaceable workers generally show lower average wages;
- the share of metropolitan population to control for the predominant urban location of some digital service economy patterns and the fact that wages (and inequalities) are generally higher in cities;
- the change of the share of people employed in low and high-skills occupations to control for the structure of occupations and wages in the labour market;
- the weight of the sectors underlying each single digital service economy value creation model to take into account the role that these sectors might have on intra-regional wage inequalities.

In the attempt of mitigating endogeneity issues, all the explanatory variables have been 1-year lagged with respect to the dependent variable.

Variables description and sources are displayed in Table 2.

The econometric analysis was performed in the frame of a random effects panel setting consisting of an 8-years period. Random effects rather than fixed effects were adopted because of the presence of time-invariant explanatory variables (i.e., the dummy variables for each digital service economy value creation model, the categorical variable for the digital service economy patterns, country dummies, risk of job automation). The Hausman test has been performed to confirm the appropriateness of the random effect model with respect to a fixed effect one. Furthermore, 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 started by estimating a Spatial Durbin Model (SDM) by using a row-standardised spatial weight matrix whose elements, the wij spatial weights, represent the row-standardised inverse distance between the centroids of the i and j regions. In all model specifications, the joint significance of the spatially lagged independent variables cannot be rejected. Therefore, the spatial lags of the explanatory variables have been included in all specifications. Furthermore, 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 below, then, are based on robust GLS.

Table 3. Description and sources of the variables

Variable	Description	Data source
Wage inequalities	Regional difference between the 90th percentile and the median of the average wage (labour cost/number of employees)	CompNet
Digital industry 4.0 regions	Dummy variable flagging regions with both a pervasive product service economy and Industry 4.0	Authors' elaboration
Digital service economy value creation models	Set of 4 dummy variables each flagging regions with a pervasive digital service economy value creation model	Authors' elaboration based on Eurostat data
Digital service economy patterns	Categorical variable representing taking value: ▪ for underdeveloped digital service economy regions ▪ for sharing economy regions ▪ for product service economy regions ▪ for online service economy regions ▪ for fully developed digital service economy regions	Authors' elaboration based on Eurostat data
Median age	Median age of the regional population	Eurostat
Foreign active population	Share of foreign active population on total active population	Eurostat
Female active population	Share of female active population on total active population	Eurostat
Human capital	Percentage of population (>15 years) with tertiary education	Eurostat
Risk of automation	Share of jobs at high risk of automation	Polimi database*
Change of low-skill employment share	Five-year average variation of the share of people employed in low-skills occupations	ISCO
Change of high-skill employment share	Five-year average variation of the share of people employed in high-skills occupations	ISCO
Employment share in manufacturing (C)	Employment share in manufacturing	Eurostat
Employment share in food and beverage service activities (I56)	Employment share in food and beverage service activities	Eurostat
Employment share in wholesale and retail trade; repair of motor vehicles and motorcycles (G)	Employment share in wholesale and retail trade; repair of motor vehicles and motorcycles	Eurostat

Note: * For details on the construction of this variable, see Capello and Lenzi (2021).

5. Results and discussion

The results obtained by estimating equations (1) and (2) are displayed respectively in Tables 3 and 4, with Table 5 zooming in on the year fixed effects (independently from any digital service economy value creation model or pattern). The two tables suggest two main messages.

First, whatever the specific value creation model considered, except from the product service economy as well as for the digital industry 4.0, their diffusion at large scale raises concerns in terms of increasing inequalities. As reported in Table 3, Column 1, a high penetration of the sharing economy business model is positively associated with intraregional wage inequalities, as shown by the positive and statistically significant coefficient associated with the pervasiveness of this business model. Simple back-of-the-envelope calculations indicate that in regions characterised by a pervasive sharing economy, intraregional wage inequalities are 15.37% higher than in all the other types of regions.[12] It can be argued that when the sharing economy is widespread and diffused, its consequences on wage distribution can be detrimental and increase intraregional wage inequalities. Differently from what we expected, the substitution of traditional activities by new ways of exchanging goods and services and by new online agents already generates displacement and reinstatement effects when it is vastly present in an area.

As shown in Column 2, a significant penetration of the product service economy does not seem to contribute to expand wage inequalities. Even though a strong specialisation in the manufacturing sector might be related with both lower average wages as well as with a request for more specialised and qualified professionals performing élite jobs, overall, the effect of this value creation model does not significantly influence intraregional wage inequalities. As hypothesised at the beginning, the limited diffusion of this value creation model within manufacturing firms may significantly constraint the impact of the product service economy on wage inequalities, with effects mainly touching on single firms or their local service providers. Similarly, as evident in Column 3, digital industry 4.0, characterised by the pervasiveness of both product service economy and industry 4.0, does not seem to be correlated with wage inequalities. This result is in line with our initial expectations. In fact, it is reasonable to think that the consequences on the labour force and labour conditions linked with digital industry 4.0 are heterogeneous and possibly divergent and they do not generate a sizeable net effect on wage inequalities.

[12] This figure is simply obtained by dividing the estimated coefficient (3.182) by the average value of the dependent variable (20.701).

In the same vein, the pervasiveness of the online service economy with short range delivery systems and local e-commerce does not intensify wage inequalities. Contrary to our expectations, in this case, the new value creation models do not affect wage inequalities. Probably, this type of digital service economy value creation model mainly allows a more efficient way of delivering products and services without dramatically changing the labour demand structure. Another potential explanation may be related with the typologies of labour contracts stipulated in this sector which could be temporary, non-standard, or self-employment-kind (and therefore not captured by the indicator used in our analysis). Measurement issues concerning the new gig-jobs being created can also be an explanation for the unexpected result. The informal nature of such jobs makes them difficult to be captured by labour official statistics.

Finally, results in Table 3, Column 5, highlights that the pervasiveness of the online service economy with a potential long range delivery system affects significantly wage inequalities. In this case, the adoption of digital technologies enables reaching new and wider markets possibly requiring expert and highly paid professionals. At the same time, greater competition and risks arise when the sector opens to broader markets rather than only the local ones. A decrease of the median wages might happen to face these altered threat conditions. Also in this case, simple back-of-the-envelope calculations indicate that in regions characterised by a pervasive online economy, intraregional wage inequalities are 12.56% higher than in the others.[13]

All the results are confirmed by Column 6 in Table 3 which simultaneously includes the four dummies for the different digital service economy value creation models.

Control variables suggest that wage inequalities tend to be particularly high in metropolitan settings characterised by a younger and more educated population, and with a lower risk of automation. This latter result is unexpected. A tentative explanation can be linked with the fact that a high risk of automation mainly characterises low-skill and low-paid occupations. If these latter occupations represent a relevant part in the local labour market, the median and top wages are likely to reduce, and their gap accordingly. Alternatively, if the risk of job automation and labour displacement is compensated by (unobserved) reinstatement effects, new and higher-quality jobs can be created, thus mitigating the rise of wage inequalities, an effect particularly likely in the case of the product service economy (Dauth *et al.*, 2021).[14]

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[13] This figure is simply obtained by dividing the estimated coefficient (2.600) by the average value of the dependent variable (20.701).

[14] We are aware that this result somewhat contradicts findings in the literature (e.g., Acemoglu and Restrepo, 2020) and we hope to examine this aspect further in future research.

The second interesting message comes from Table 4. As previously highlighted, in fact, even if the consequences of each specific digital service economy value creation model are interesting per se, the reality suggests that different value creation models combine in space. Therefore, their respective impacts and consequences on labour market inequalities might be strengthened but also mitigated. Table 4 displays the results obtained through the estimation of equation (2), which highlights the effect of the different digital service economy patterns on wage inequalities.

Quite interestingly, the output of this second set of estimates shows that the overall effect of digital service economy on intraregional wage inequalities is strong and statistically significant in the case of the fully developed digital service economy. In regions characterised by a fully developed digital service economy, intraregional wage inequalities are more than 15% higher than in regions characterised by an underdeveloped digital service economy.[15]

Table 4. Digital service economy value creation models and wage inequalities: main results

Dependent variable: wage inequalities	(1)	(2)	(3)	(4)	(5)	(6)
Sharing economy	3.182***					3.014***
	(0.915)					(0.895)
Product service economy		-0.198				-0.267
		(0.725)				(0.647)
Digital industry 4.0 regions			0.386			
			(0.850)			
Online service economy (short range delivery system)				1.069		0.577
				(1.110)		(1.007)
Online service economy (long range delivery system)					2.600***	1.813**
					(0.918)	(0.891)

Note: N = 164 x 6 = 1,312. Country and year fixed effects as well as their interaction included. Full controls and tests are displayed in Table A5 in Annex. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Interestingly, the sharing economy pattern also shows a significant effect on intraregional wage inequalities. A possible interpretation of this result is that the sharing economy may generate substitution effects on traditional offline businesses and their employees, leading to the erosion of traditional offline actors market share, a greater competition with traditionally better paid

[15] This figure is simply obtained by dividing the estimated coefficient (3.231) by the average value of the dependent variable (20.701).

jobs, being crowded out if not replaced by lower paid one, and, finally, a rise of wage inequalities. In terms of magnitude, regions with a pervasive sharing economy, intraregional wage inequalities are around 11% higher than in regions characterised by an underdeveloped digital service economy.[16]

In the other cases, even if each of the single digital service value creation model is highly pervasive in the local economy, its effects on intraregional wage inequalities are overall nil.

Table 5. Digital service economy patterns and wage inequalities

Dependent variable: wage inequalities	(1)
Sharing economy	2.368**
	(0.997)
Product service economy	0.411
	(1.103)
Online service economy	0.339
	(1.147)
Fully developed digital service economy	3.231***
	(1.241)

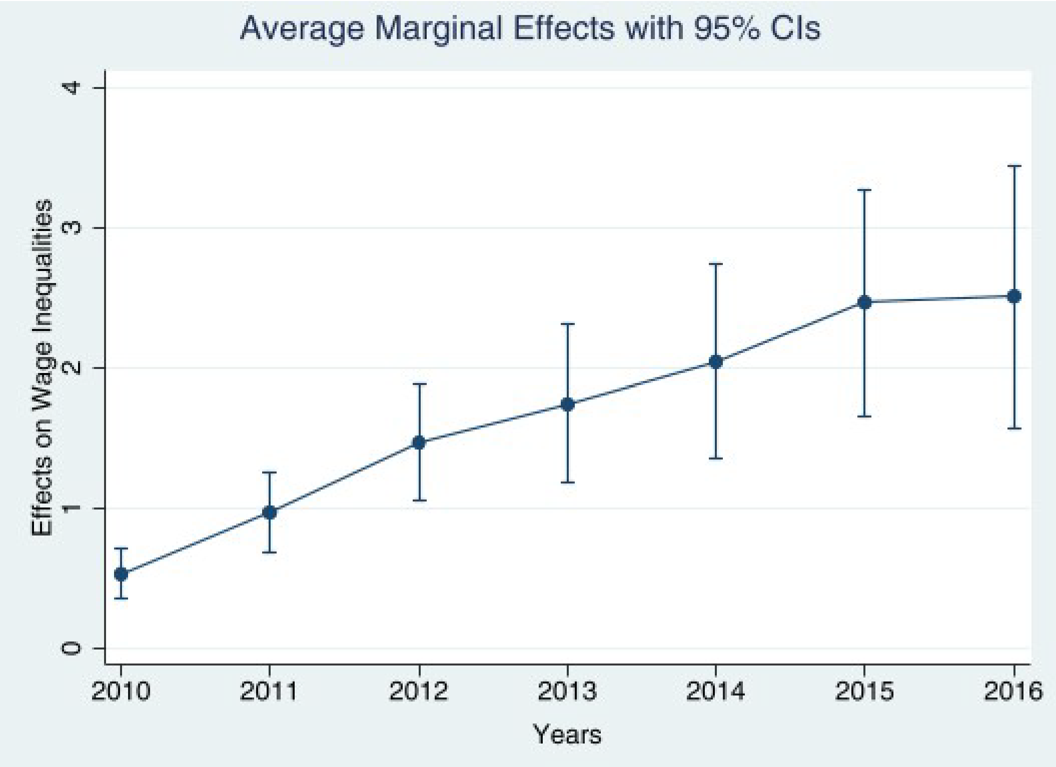
Note: N = 164 x 6 = 1,312. Country and year fixed effects as well as their interaction included. Full controls and tests are displayed in Table A5 in Annex. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The last interesting result come from the estimation of year fixed effects, independently from any kind of digital service economy value creation model or pattern. For the sake of simplicity, Figure 5 reports only the estimated marginal effects from equation 2, which highlight a continuous increase in wage inequalities over time, independent from the role of any specific digital service economy value creation model. This result is aligned with findings and warnings raised in the literature as well as in the press (Autor *et al.*, 2020; Rullani & Rullani, 2018) pointing to what has been identified as the 'automation anxiety' (Autor, 2015). Our results suggest that the rise of wage inequalities takes place even in absence of technological transformations and only some of them, namely the sharing economy and the combination of all digital service transformations, lead to amplify intraregional wage inequalities. This result raises relevant warnings and concerns deserving further investigation.

All together, these results highlight important messages and policy implications, discussed in the conclusive section.

[16] This figure is simply obtained by dividing the estimated coefficient (2.368) by the average value of the dependent variable (20.701).

Figure 5. Wage inequalities: year marginal effects



6. Conclusions

The upsurge in wage inequalities largely predicted in the literature, especially dealing with the US case (Acemoglu & Restrepo, 2020; Autor *et al.*, 2020; Brynjolfsson & McAfee, 2014) and feared in the media debate, has found some confirmation in the analysis conducted in this paper (Figure 4 and Figures A5.1 to A5.5). Our conclusions, however, enable also nuancing if not mitigating some of the most severe and pessimistic forecasts on the labour market consequences of the diffusion of the new technologies.

Although the rapid diffusion of advanced digital technologies in services and the consequent emergence of new digital service economy value creation models can conceptually widen intraregional wage inequalities, the empirical analysis shows that reality is more nuanced.

Our empirical results highlight that the pervasiveness of each single digital service economy value creation model in isolation is not sufficient to affect intraregional wage inequalities, except for the sharing economy. It is rather the spatial combination of all value creation models that matters in affecting such inequalities, adding, or even multiplying, the effects of single transformations.

In fact, when a new digital service economy value creation model prevails as the unique one in a region, its impact on intraregional wage inequalities is limited. In the case of the product service economy, for instance, the limited impacts are probably the outcome of a reduced weight of this type of business model on local economies. Even if some impacts on wages can be conceptually envisaged, particularly affecting and improving the ones of high-skill, élite workers, these effects do not sizeably alter the structure of occupations and wages in local labour markets. When instead the different digital service economy value creation models coexist, their effects on wage inequalities can sum up.

Taken together, these results suggest that popular fears about the possible consequences of the diffusion of the new technologies are not fully misplaced and wage inequalities do rise over time. However, regions are not similarly exposed to these risks and only some of them are actually experiencing a deterioration of their wage inequality conditions. This conclusion has some relevance in terms of policy warnings. In fact, for the most exposed regions, the ones characterised by a sharing economy or by a fully developed digital service economy patterns, wage inequalities can represent an urgent and immediate issue requiring timely policy reply and intervention.

Differently, in other regions not yet similarly exposed to these risks, such as regions with a predominant product service economy or an online economy only, anticipatory policy interventions could be appropriate to avoid a widening of intraregional wage disparities in the future once the new digital service economy value creation models will become dominant. In both types of regions, however, tackling wage inequalities is likely to represent a priority in the policy agenda in the next future.

Appendix

A1. Measuring the regional share of firms with at least 1% of their turnover obtained through online sales

Data on the share of firms with at least 1% of their turnover obtained through online sales – the proxy for the adoption of advanced digital technologies – has been obtained from EUROSTAT and is available at the national level with a sufficient sectoral breakdown starting from 2009. EUROSTAT makes available only the share of firms selling online, not the actual number of firms. In order to compute the number of firms with online sales at the national level to be apportioned at the regional level, data on sectoral local units have been used, sourced from EUROSTAT Structural Business Statistics (SBS).

National data have been apportioned at the regional (NUTS 2) and sectoral (i.e. C, G,I56) level by applying the simple average of two weights accounting for the following aspects:

- the relevance of the sector in the region with respect to the country. The use of this weight follows the expectation that regional sectoral online sales depend on regional sectoral specialisation, i.e. regions that are more specialised in a specific sector contribute more to national sales online in the same sector and have, thus, a greater share of firms selling on line;
- the level of internet access in the region compared with the country. The use of this weight follows the expectation that online sales are more diffused in regions with a more digitalised population, i.e. in regions more prone to adopt new technologies. Using the population with internet access as the second weight in the digitalisation indicator depends on the fact that we are interested in the intensity of use of digital technologies regardless of the presence of a relatively advanced digital infrastructure.

In particular, the two weights have been computed by applying the following formulas:

- $w_1 = (Emp_{r,s} / Emp_{n,s})$

where *Emp* stands for the number of employees, *r* the region, *n* the country, *s* the sector (i.e. C, G, I56, respectively). As noted above, sectoral employment data has been sourced from SBS;

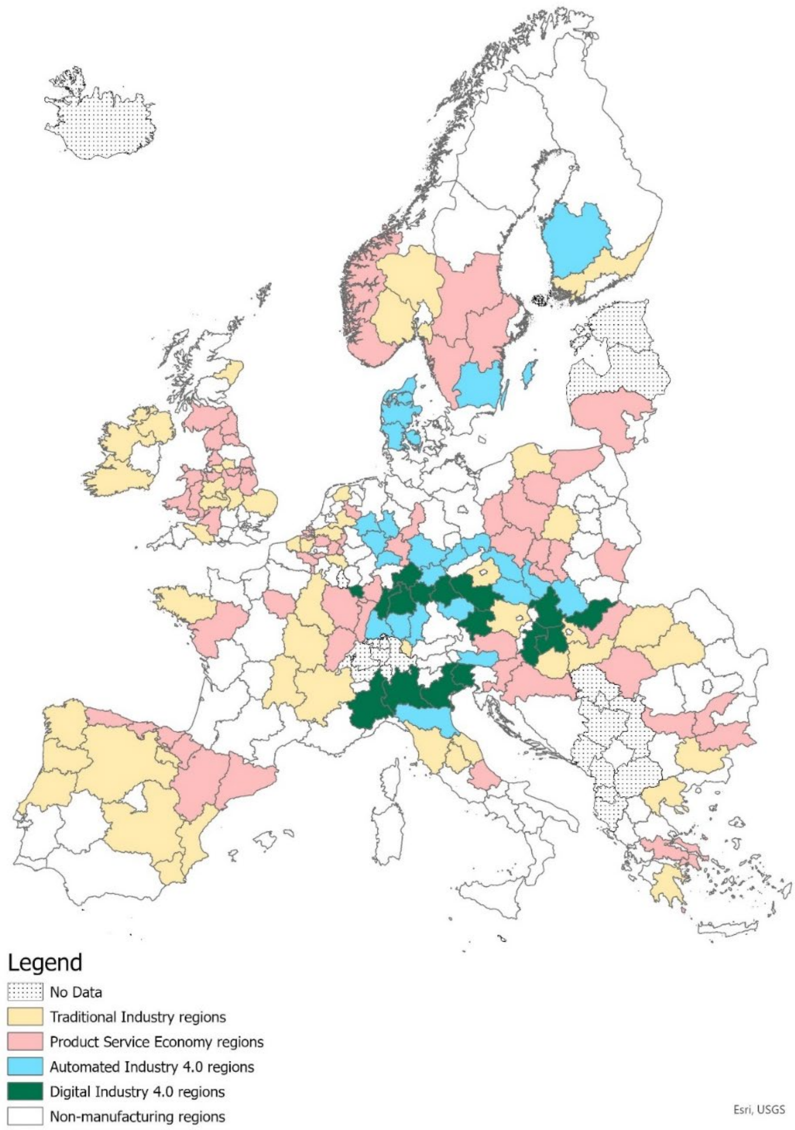
- $w_2 = (Pop_{r,int} / Pop_{n,int})$

where $Pop_{r,int}$ stands for the number of inhabitants in region *r* having access to internet and $Pop_{n,int}$ stands for the number of inhabitant in country *n* having access to internet. EUROSTAT makes available only the share of persons with internet access. In order to compute w_2, the number of inhabitants in the region (respectively, the country) with internet access was obtained by multiplying the shares provided by EUROSTAT times the regional (respectively, national) population.

By this apportionment methodology, it was possible to compute the number of firms with online sales at the regional level. The regional/sectoral share of firms selling online was obtained by dividing, for each sector, the number of firms with online sales at the regional level by the number of local units obtained from SBS.

A2. Geography of the combination between product service economy and Industry 4.0

Figure A2.1. Product service economy and Industry 4.0: a map of their combinations



A3. Regional digital service economy patterns

Table A3 shows the results of the k-means cluster analysis used to group European regions according to their predominant digital service economy value creation model and, specifically, for each digital service economy pattern, the frequency of regions by type of digital service economy value creation model.

Table A3.1. Regional patterns of digital service economy: results from the k-means cluster analysis

Value creation models in the digital service economy	Absence (%)	Potential (%)	Niche (%)	Pervasive-ness (%)
Underdeveloped digital service economy (36 regions)				
Product service economy	75	25	-	-
Sharing economy	22.22	50	22.22	5.56
Online service economy (short range delivery system)	75	25	-	-
Online service economy (long range delivery system)	72.22	27.78	-	-
Sharing economy (72 regions)				
Product service economy	-	-	11.11	88.89
Sharing economy	37.50	31.94	19.44	11.11
Online service economy (short range delivery system)	37.50	33.33	11.11	18.06
Online service economy (long range delivery system)	44.44	34.72	13.89	6.94
Product service economy (49 regions)				
Product service economy	79.59	16.33	4.08	-
Sharing economy	79.59	12.24	8.16	-
Online service economy (short range delivery system)	65.31	24.49	10.20	-
Online service economy (long range delivery system)	-	40.82	22.45	36.73
On-line service economy (45 regions)				
Product service economy	73.33	17.78	8.89	-
Sharing economy	8.89	15.56	46.67	28.89
Online service economy (short range delivery system)	4.44	8.89	53.33	33.33
Online service economy (long range delivery system)	17.78	33.33	22.22	26.67
Fully developed digital service economy (71 regions)				
Product service economy	-	12.68	15.49	71.83
Sharing economy	5.63	19.72	45.07	29.58
Online service economy (short range delivery system)	5.63	11.27	47.89	35.21
Online service economy (long range delivery system)	-	-	42.25	57.75

A4. Digital service economy patterns and their socio-economic context conditions.

Table A4 presents the output of an ANOVA exercise aimed at highlighting the key socio-economic profile of different digital service economy patterns. Values are expressed as location quotients with respect to the country average.

Table A4.1. Digital service economy patterns and their socio-economic context conditions. Results from ANOVA

Variable	P-value	Under-developed digital service economy	Sharing economy	Product service economy	On-line service economy	Fully developed digital service economy
Regional adoption intensity						
Online sales C	0.000	1.02	0.92	0.82	1.05	1.15
Online sales consumer to consumer	0.000	0.84	1.17	0.78	0.87	1.13
Online sales I56	0.020	0.91	1.02	0.88	1.08	1.10
Online sales G	0.000	0.93	0.93	0.85	1.05	1.10
Regional probability to adopt						
Specialisation C	0.000	0.82	0.94	1.22	1.06	1.02
Share of internet use	0.000	0.92	1.04	0.93	0.96	1.04
Specialisation I56	0.012	1.06	1.03	0.90	0.96	0.99
Specialisation G	0.044	0.93	1.03	0.93	0.97	1.01
Socio-economic context						
Personal wealth	0.002	0.81	1.03	0.82	0.95	1.05
Human capital	0.004	0.88	0.99	0.91	0.99	1.03
Innovation	0.011	0.67	1.15	0.65	0.87	1.12
Urbanisation	0.000	0.65	0.81	0.39	1.06	1.07
Median age	0.001	1.02	1.01	1.03	0.99	0.99
Economic dynamics						
Productivity growth (2008-2012)	0.003	0.87	1.11	0.97	0.21	1.04
Productivity growth (2013-2017)	0.014	-0.55	1.75	0.34	1.24	1.12
Entrepreneurship	0.001	0.92	0.92	0.75	0.94	1.04
Labour force composition						
High-skills share	0.021	0.83	0.98	0.89	0.94	0.96
Low-skills share	0.002	1.09	0.97	1.04	1.02	0.98
Wage polarisation	0.003	0.87	0.96	0.84	0.92	1.01
Knowledge intensive services	0.001	0.91	1.01	0.95	0.97	1.01
Internet use						
Internet use – social purposes	0.000	0.92	1.05	0.91	0.97	1.04
Internet use – banking purposes	0.000	0.85	1.05	0.87	0.96	1.11
Internet use – political purposes	0.000	0.87	1.05	0.84	0.98	1.06

A5. Geographical distribution of the median and 90th percentile of the labour cost per employee variable

Figure A5.1. Labour cost per employee – median (2008)

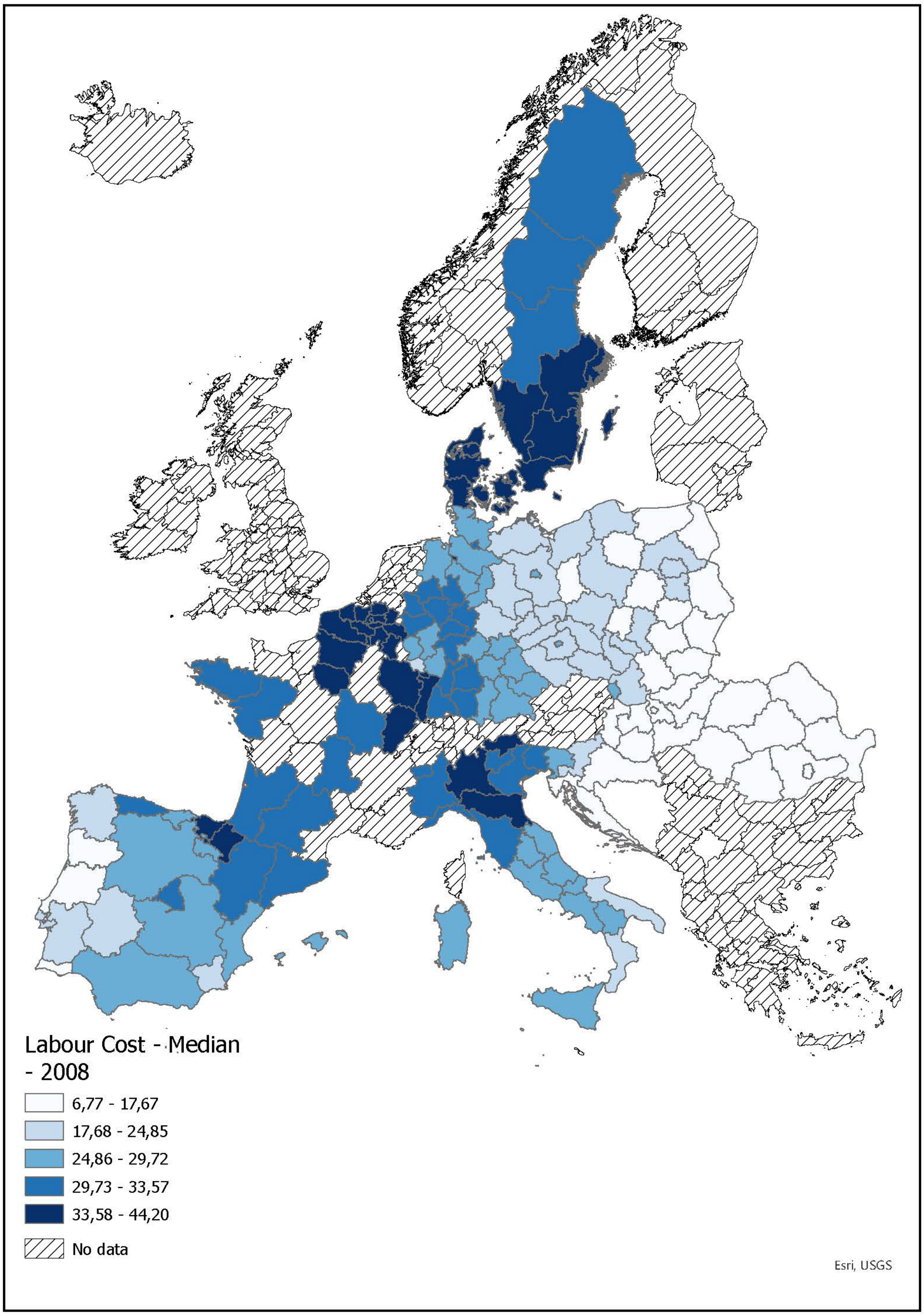


Figure A5.2. Labour cost per employee – median (2016)

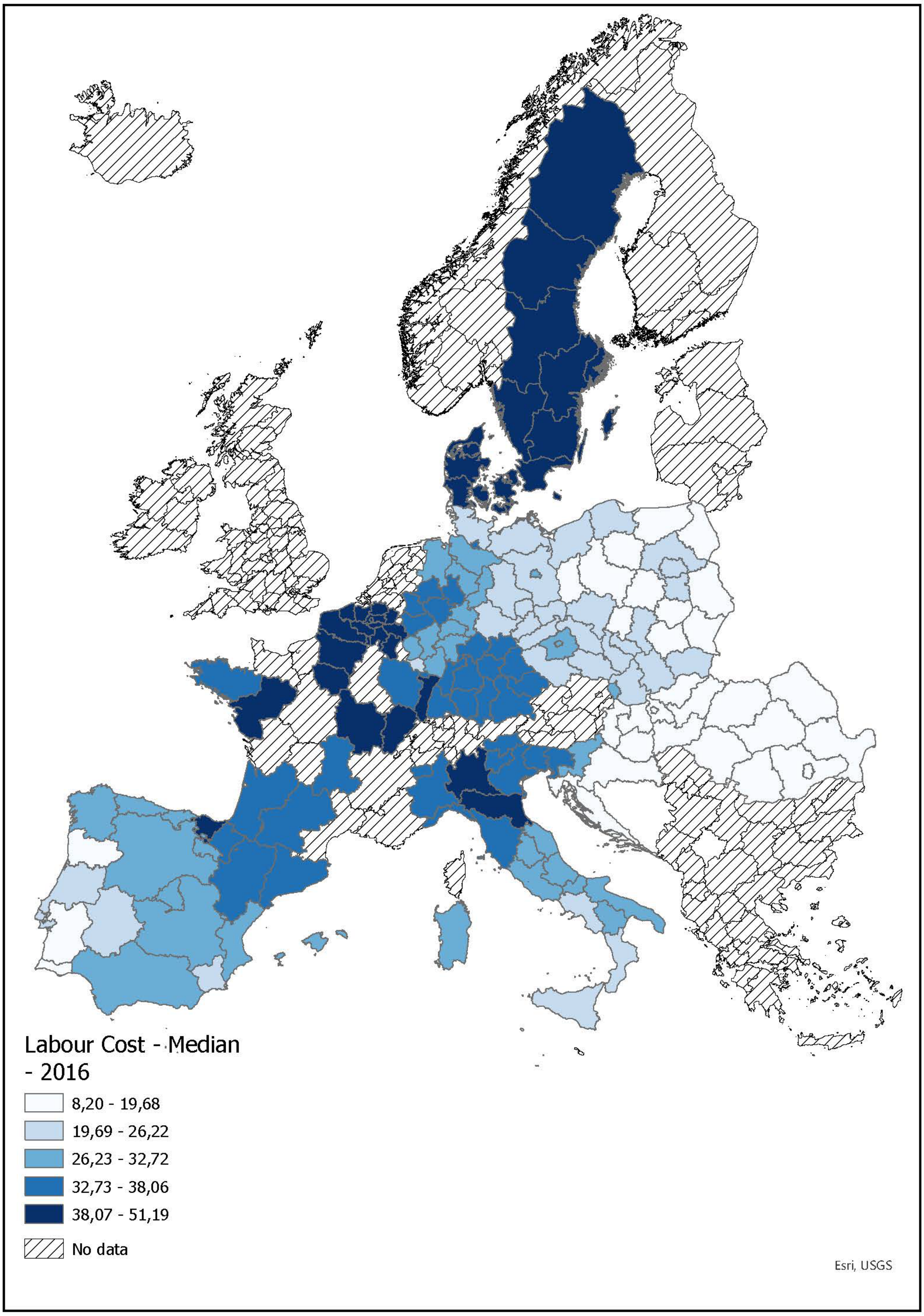


Figure A5.3. Labour cost per employee – 90th percentile (2016)

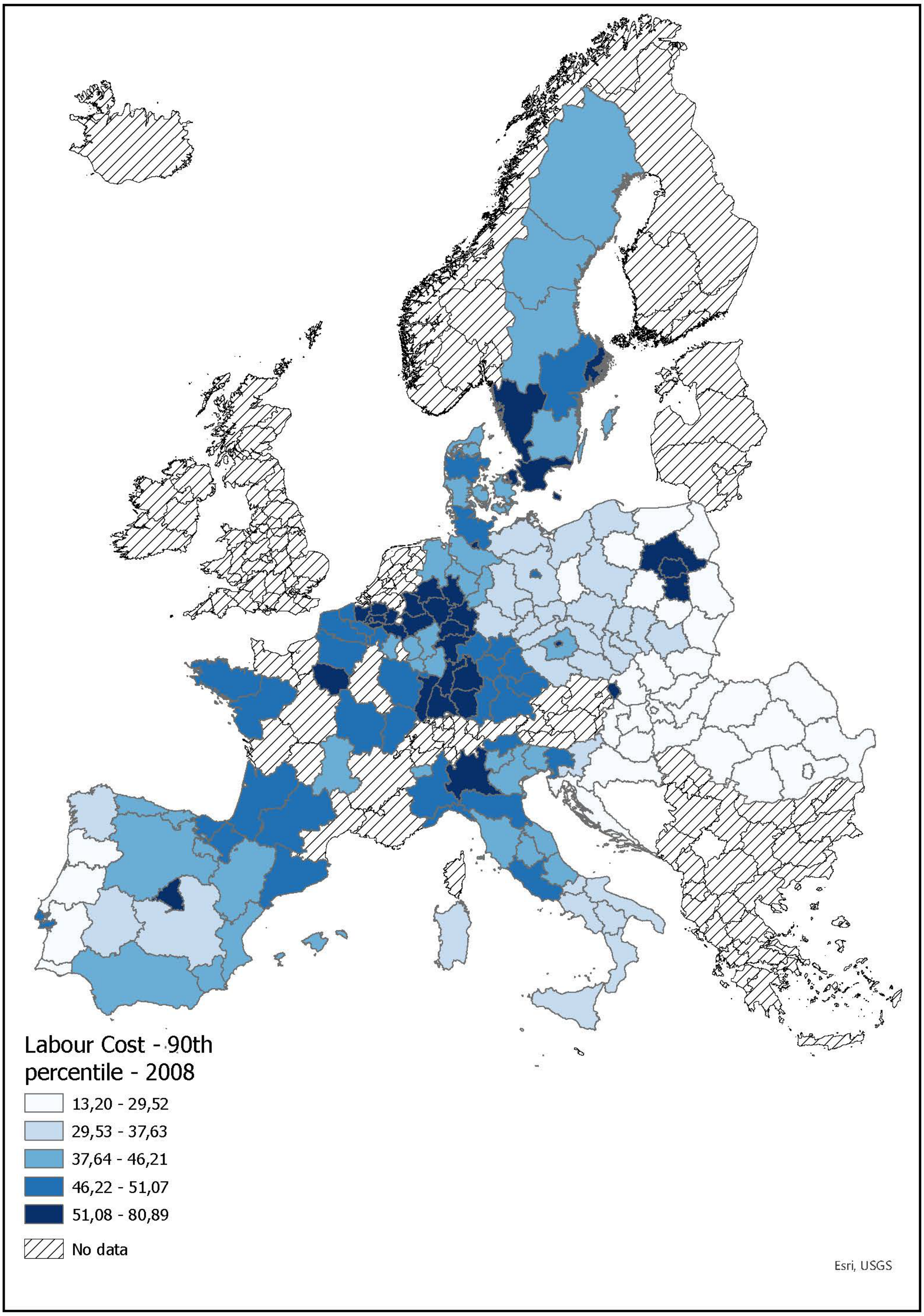


Figure A5.4. Labour cost per employee – 90th percentile (2016)

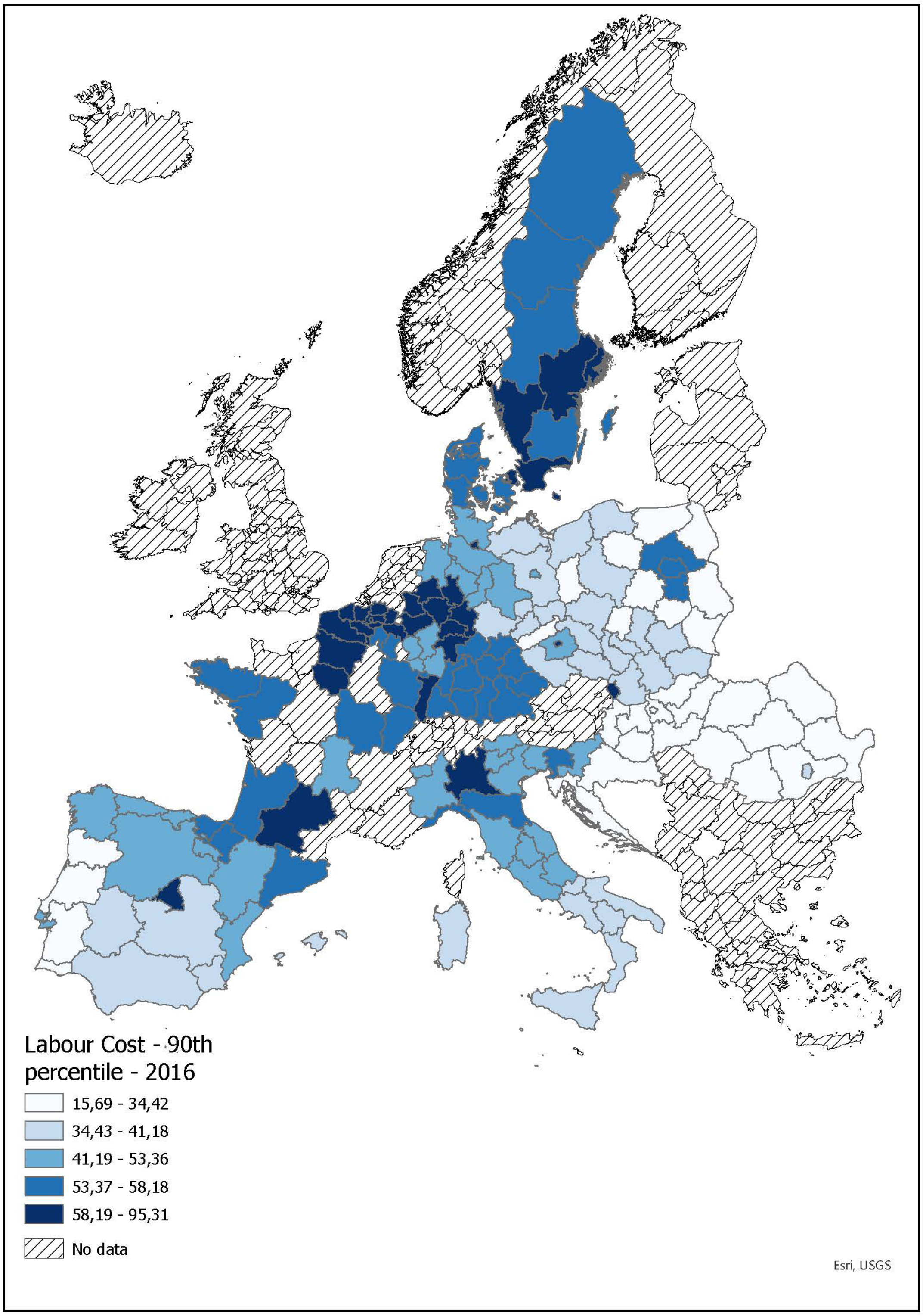
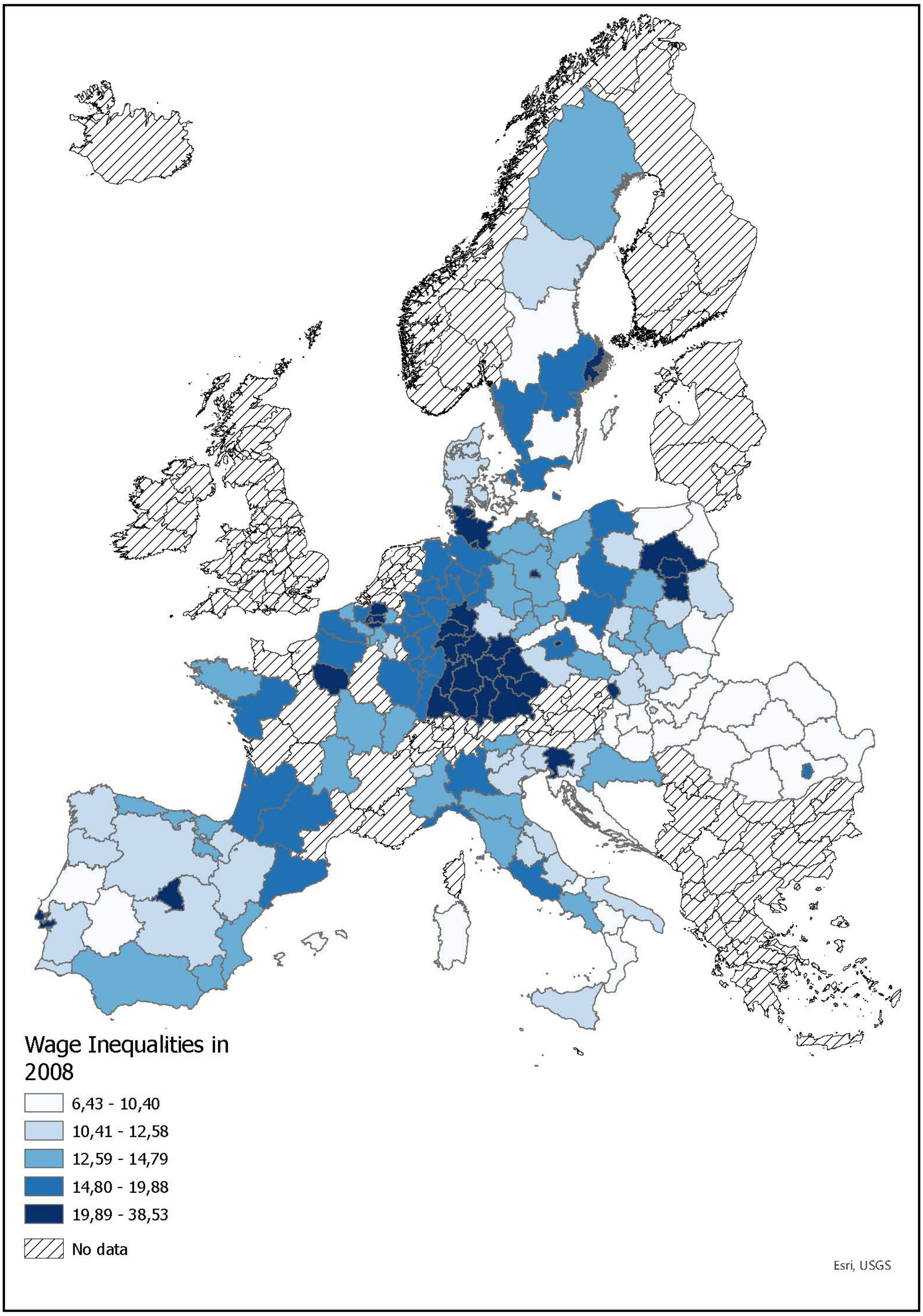


Figure A5.5. Intraregional wage inequalities (2008)



A6. Regression results

Table A6.1. Digital service economy value creation models and wage inequalities

Dependent variable: wage inequalities	(1)	(2)	(3)	(4)	(5)	(6)
Sharing economy	3.182***					3.014***
	(0.915)					(0.895)
Product service economy		-0.198				-0.267
		(0.725)				(0.647)
Digital industry 4.0 regions			0.386			
			(0.850)			
Online service economy (short range delivery system)				1.069		0.577
				(1.110)		(1.007)
Online service economy (long range delivery system)					2.600***	1.813**
					(0.918)	(0.891)
Median age	-0.364**	-0.360**	-0.350**	-0.374***	-0.341**	-0.368**
	(0.146)	(0.150)	(0.153)	(0.145)	(0.139)	(0.144)
Foreign active population	-3.143	-2.686	-2.625	-2.492	-3.205	-3.917
	(6.317)	(6.193)	(6.310)	(6.011)	(6.309)	(6.515)
Female active population	-1.659	-0.085	0.508	0.704	-1.735	-3.253
	(5.679)	(5.663)	(5.619)	(5.692)	(5.628)	(5.949)
Human capital	14.794***	14.074***	14.646***	14.019***	13.788***	14.406***
	(3.598)	(3.629)	(3.600)	(3.594)	(3.714)	(3.660)
Metropolitan population	5.265***	6.319***	6.065***	5.727***	5.151***	4.494***
	(1.089)	(1.217)	(1.202)	(1.185)	(1.150)	(1.005)
High-skills	-0.599	-0.558	-0.439	-0.486	0.020	-0.096
	(1.927)	(1.946)	(1.862)	(1.920)	(1.877)	(1.939)
Low-skills	3.628	3.628	3.832	3.715	3.493	3.569
	(2.429)	(2.427)	(2.375)	(2.435)	(2.432)	(2.429)
Risk of automation	-17.754*	-22.371**	-22.035**	-21.197**	-23.002**	-16.029*
	(9.179)	(9.777)	(10.252)	(9.774)	(10.298)	(9.540)
Share of employment in manufacturing (C)		0.394	1.887			
		(5.267)	(4.816)			
Share of employment in food and beverage service activities (I56)				1.069		
				(1.110)		
Share of employment in wholesale and retail trade, repair of motor vehicles and motorcycles (G)					1.652	
					(4.897)	
Share of employment in sectors C+I56+G						1.734
						(3.327)
Constant	27.909***	27.544***	31.784***	28.933***	27.031***	27.726***
	(6.414)	(6.532)	(6.731)	(6.345)	(5.969)	(6.679)
R2	0.74	0.71	0.68	0.71	0.71	0.76
Hausman test (p-value)	1.0000	0.9723	1.0000	1.0000	0.9859	1.0000
Wald test – spatial lag (p-value), SLX	0.0006	0.0026	0.0024	0.0013	0.0026	0.0001
Wald test – spatial lag of the dependent variable (p-value), SDM	0.664	0.583	0.582	0.582	0.693	0.707
Wald test – spatial lag of the independent variable (p-value), SDM	0.0004	0.0016	0.0014	0.0007	0.0016	0.0000
Wald test – spatial error (p-value), SEM	0.678	0.671	0.671	0.722	0.609	0.577
Spatial lags of Xs	YES	YES	YES	YES	YES	YES

Note: N = 164 x 6 = 1312. Country and year fixed effects as well as their interaction included. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A6.2. Digital service economy patterns and wage inequalities

Dependent variable: wage inequalities	(1)
Sharing economy	2.368**
	(0.997)
Product service economy	0.411
	(1.103)
Online service economy	0.339
	(1.147)
Fully developed digital service economy	3.231***
	(1.241)
Median age	-0.370**
	(0.145)
Foreign active population	-4.212
	(6.561)
Female active population	-3.212
	(5.846)
Human capital	15.130***
	(3.706)
Metropolitan population	5.294***
	(1.107)
High-skills	-0.143
	(1.942)
Low-skills	3.551
	(2.432)
Risk of automation	-20.828**
	(9.101)
Share of employment in sectors C+I56+G	1.903
	(3.306)
Constant	26.638***
	(6.592)
Observations	1,312
Number of nuts2_code	164
R2	0.74
Hausman test (p-value)	0.9976
Wald test – spatial lag (p-value) SLX	0.0157
Wald test – spatial lag of the dependent variable (p-value), SDM	0.895
Wald test – spatial lag of the independent variable (p-value), SDM	0.000
Wald test – spatial error (p-value), SEM	0.569
Spatial lags of Xs	YES

Note: N = 164 x 6 = 1312. Country and year fixed effects as well as their interaction included. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

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