Industry 4.0 and big data: role of government in the advancement of enterprises in Italy and UAE

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Abstract: Industry 4.0 and big data act as a lever for increasing new competition between companies as it becomes too large and complex to be faced or internalised by these companies alone, even large ones. This article examines Industry 4.0 and big data in Italy and the UAE. Very structurally different countries but similar in apprehending, this is the 'age of data' and already realised significant technological leaps on their own territories. Active intervention of government becomes crucial and central in the elaboration of industrial and technological policies towards the enhancement of a dynamic ecosystem and interactive environment where data can flow more smoothly along the production chain. In order to attain such systemic and organisational environment, governments create its solid foundation initially by fully utilising the architecture of big data internally. This paper addresses the current role of government and further actions needed as a stimulus, creator and originator of a cognitive and interactive environment for big data.

Keywords: big data; Industry 4.0; internet of things; IoT; mass customisation; open data; cyber physical system; CPS: human resources; flow of knowledge; innovation; government; Emilia-Romagna; Italy; UAE.

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1 Introduction

We are experiencing an unprecedented revolution, which involves ways of producing goods and services and creating value. The way knowledge is created, used and learned has changed. This revolution, now often falling under the so-called Industry 4.0 has commenced in Europe, and mainly originated from the manufacturing sector and currently involving also a range of different sectors such as that of services, financial and insurance sectors, hence, involving more and more productive sectors in the society as a whole.

This digital revolution has a characteristic that distinguishes it from all previous revolutions: it is accompanied by an immense production of data and information that must be handled, stored and processed.

Industry 4.0 is not simply a defining framework that involves a set of technological and organisational concepts. This term describes the need for a strategy of a country as a whole aimed at guiding this new economic revolution, placing cyber physical system (CPS) central in this process, and assisted by big data.

The term Industry 4.0 combines two different approaches: the European and the American (Viticoli, 2017). The profound difference between the two models is described by two elements: the production context and the size of enterprises. Europe is an economic block strongly based on manufacturing[1], characterised by the almost total presence of SMEs[2] (accounting for over 90% of firms). The large industrial, financial, and service groups, scarcely present in Europe, do not reach the dimension of the US giants in number and size. Such European structural characteristics imply adequate development strategies being smaller requiring greater cooperation with the public (government). This European model prefers optimisation of the manufacturing sector, the *smart factory*, while the US model aims additionally at improving services and the economic system as a whole, focusing on strengthening the digital infrastructures. Such differences have implications for the transfer and management of information flows. The European model focuses on defining common languages and standards for data collection and storage, especially within big data. The US approach focuses more on interoperability of heterogeneous data by considering the creation of platforms using flexible production systems that are able to be completely reconfigurable, changing intelligent design, production, logistics and supply chain management (SCM), and giving enterprises themselves the lead to guide the dynamics of this revolution. This cross-platform technology will be able to provide solutions to address the problem of highly personalised products (Simpson et al., 2014).

Moving within the European development model, the present work investigates the role of government in stimulating the productive system through the adoption of enabling technologies, in particular big data and in removing obstacles and barriers that slow down or prevent the adoption of what big data and Industry 4.0 can potentially offer.

Industry 4.0 and big data are closely connected. Enterprises, which apply the enabling technologies of Industry 4.0, on the one hand, use the information flows coming from the outside, on the other hand, they produce huge amounts of data, mainly generated by the application of internet of things (IoT). The firm becomes a place of heterogeneous data and information flows; whose ownership belongs to different subjects. First of all, there is 'internal' production of data by manufacturing companies, resulting from the use of IoT. Sensors applied to production and packaging machines, together with sensors placed in intelligent warehouses, and up to the composition of final products ready for shipment. Thousands of sensors are scattered along the production chain that continuously transmit data, which must be coordinated in real time to speed up the interconnection between production and logistics phases. This is data that through cloud computing can be reprocessed for predictive purposes (predictive maintenance), or for estimating future production flows. Such streams of information that flow between firms in the supply chain (Kusrini et al., 2016; Mishra and Shekhar, 2015), among hundreds of firms that communicate with each other, is shown in the case of traceability of food products in the agro-industry, the so-called blockchain. Secondly, further data production is associated with the relationship between consumer and purchased product: between consumer and retail companies, or even directly between consumer and producers in the case of online purchases as in *real time production*. Thirdly, there is the huge mass of data composed of all the fragments of information that spread our digital identity on a daily basis, for example, from the use of social networks (Facebook, Twitter and Instagram), in addition, information left in search engines, visited websites, hotels booked and so on. Such large amount of data that can be processed to improve our lives and make our choices more efficient and faster. This is also data that can be processed towards direct production of new goods and services or to intensify marketing activities, or to make the managerial control system (MCS) more accurate, which in turn is strongly connected with product or service innovations (Arcari et al., 2018). Fourthly, there is that data related to financial institutions (access to credit and solvency of companies and individuals) and insurance institutions. Finally, there is the data collected by public administrations, data on the health of people, collected by health facilities, the number and type of drugs sold by pharmacies, and personal and geographical data. To these, we also add all the data collected by research centres and universities, for instance on weather and climate change, air quality, land morphology and water resources and so on.

These immense and valuable databases are subject to two trade-offs; its correct calibration will be crucial for future development of business competitiveness. The so-called question of *open data*, and understanding whether this data, in an aggregate and protected form can be made available to firms that request it. A second issue concerns the privacy and security of stored and processed data. The European Union has enacted the General Data Protection Regulation (GDPR)[3], which aims at strengthening and protecting personal data of its citizens more homogeneously, by giving people more control over their information and by obliging companies to handle data more carefully.[4]

Main challenges are hence expected to emerge, which transcend the walls of individual firms and also the production chain itself, in which government can play a decisive role for the competitiveness of companies and improvement of the quality of life of its citizens.

The main objective of this research is understanding the close connection between Industry 4.0 and big data and the possible role of government to stimulate this connection. Taking into consideration, the small operational dimension of most of the Italian and UAE enterprises falling under the category of small and medium-sized enterprises (SMEs), not comparable to the US reality and economic giants, the role of government becomes fundamental for the development of these enterprises in terms of data production, regulation and interoperability. The key point is understanding current role of public administrations and actions needed for further development. The strategies of Industry 4.0 include both potentials and obstacles that these enterprises are facing and the role of government in the removal of such barriers that are slowing down the adoption of big data in these operational contexts.

The aim of this study was to examine Industry 4.0 and big data in Italy and the UAE. For the Italian companies, the objectives of this paper were fully met, however, partially met for the study of UAE companies. Limitations in terms of existing literature and particularly lack of primary research in the field. Thus, opportunities for further research would require the need for quantitative research and qualitative considerations from a sample of large and small-medium UAE-based companies that either use or produce big data and analytics, and ICT companies that offer solutions and services related to big data, in order to fully comprehend the economic context of big data and Industry 4.0 in the UAE.

The rest of this paper follows with main key analysis from literature review of Industry 4.0 and big data, followed by the methodology, the role of the Emilia-Romagna Government and survey results (concerning Italian enterprises). A dedicated section follows analysing the UAE context and program analysis. Finally, the paper ends with a discussion and conclusions identifying key comparisons between the Italy and the UAE along with recommendations to policy makers.

2 Literature review

2.1 Industry 4.0

The Industry 4.0 term appeared for the first time at Hannover Fair in 2011 and was proposed to develop the German economy (Mosconi, 2015; Roblek et al., 2016). Since its origins, it has been used as a synonym for CPS in the production sector (Vogel-Heuser and Hess, 2016).

Over time, the term Industry 4.0 expanded to include multiple definitions: IoT, big data, cloud manufacturing (cloud computing), and smart manufacturing; additive manufacturing technologies (3D). Many definitions of Industry 4.0 have been articulated according to different perspectives and research fields. Industry 4.0 can be defined as a new level of organisation and management of the value chain along the product life cycle, or as a term that combines technologies with concepts of the value chain, where within the modular structure of the intelligent factory (smart factory), the CPS monitors the physical process by creating a virtual copy of the physical world (Hermann et al., 2016), and cloud manufacturing for Industry 4.0 (Thamesa and Schaeferb, 2016).

However, what characterises the fulcrum of Industry 4.0 is the use of available data, where production technologies can be improved and transformed by the CPS, which enables all the physical processes and information flows to be available when and where they are needed across holistic manufacturing supply chains, multiple industries, SMEs and large companies (Zhong et al., 2017). The CPS not only represents the convergence between the physical and the digital world, establishing global networks that incorporate machinery, storage systems and production facilities (Shafiq et al., 2015), but also 'systems of collaborating computational entities' in connection with the physical world (Monostori et al., 2016). This combination of information (immaterial world) and physical components (materials), decentralised and autonomous becomes the most effective lever to improve industrial performance. This takes the name of interoperability, the ability of two systems to understand each other using the same functionality (Chen et al., 2008) and represents one of the major advantages of Industry 4.0. Two systems can exchange heterogeneous information and knowledge leading to application solutions in the different levels of business processes. Enterprise architecture has evolved from one that was mainly internal in the typical enterprise during the '80s into a dynamic and innovative source for interactions and interoperability, closely connected with the whole surrounding environment. The enterprise architecture consists of three sub-systems that interact with each other:

1 physical sub-system, including human and technical agents

2 decision sub-system, where planning, decision and monitoring actions are made

3 information sub-system, where information flows as well as process, storage and retrieval actions on data (Romero and Vernadat, 2016).

Each of these sub-systems can itself be viewed as a complex system, so enterprise architecture can be configured as system of system (Ackoff, 1972; DiMario, 2010). The new technologies allow a close interaction between these three sub-systems, not only within the enterprise but also with the sub-systems of the value chain in which the enterprise is integrated. According to Romero and Vernadat (2016), we can observe various evolutions of the enterprise information systems (EIS), in which increases the degree of complexity and information management by the enterprise. After the introduction of the first computers, IT systems started to play a supporting role in business processes, through information analysis and reporting. In the ‘80s, the task moved towards planning production and resources through manufacturing resources planning (MRP). Finally, in the ‘90s, enterprise resource planning (ERP) was born, integrating various databases to carry out elaborations on personnel and quality management. Today, the most advanced version of ERP manages IT systems that support intra-organisational collaboration between logistics, procurements, sales, marketing, human resources and finance (Callaway, 2000; Møller, 2004). In the new millennium, the use of ERP has gone beyond the walls of the enterprise in terms of organising supply chains, including customers and the sales side of the marketplace through SCM. The process follows the product from the acquisition of raw materials stage to its transformation into finished products and up to the logistics and distribution stages (Kusrini et al., 2016; Mishra and Shekhar, 2015; Muzumdar and Balachandran, 2001).

The CPS, acts in closely with the spread of IoT which is the most widespread among Industry 4.0 manufacturing companies. By connecting humans with machines, IoT integrates knowledge between organisations (Lu, 2017), which, once developed, increase efficiency and effectiveness in the management of the company and the value chain. Production decisions will not be the sole prerogative of the relationship between producer and seller but will have an increasing role given consumer choices managed in real time, fading the division between manufacturing and services sector, as industrial products will be associated with advanced services (Viticoli, 2017). In 1999, Kevin Ashton first used the term IoT (Ashton, 2009). The term illustrated the power of connecting radiofrequency identification in the field of SCM (Lee et al., 2017). Since then, the term has gained more attention in industry and academia (Bandyopadhyay and Sen, 2011), placing IoT between the revolution of the internet and the metamorphosis of objects (Sundmaeker et al., 2010). Thus, the term IoT has become broader, describing technological developments in which internet connectivity embraces everyday subjects that modify its functions. Today, there are various definitions of IoT, which we can divide into four categories:

1 as intelligent objects

2 an extension of the internet

3 a global network infrastructure

4 as the interaction of information (Lee et al., 2017).

IoT embraces different fields of knowledge, such as telecommunications, informatics, electronics and social science in order for it to develop (Atzori et al., 2010). In this revolution, the role of the government assumes an unprecedented strategic importance, both in the supply and use of data and in ensuring human resources with adequate training to cope with the change. To fully exploit the enormous potential and benefits of IoT requires adequate government action that must intervene with regulatory policies in different aspects: technological, social and legal, addressing the challenges of interoperability and cybersecurity (Lee, 2019).

Both computer systems and IoT need to process an impressive quantity of data. Therefore, the so-called big data today is placed at the strategic heart of many production and service companies.

2.2 Big data

Both computer systems and IoT require the processing of an impressive amount of data. Therefore, today the so-called big data is at the heart of many manufacturing and service companies' action plans. The volume and level of detail of data captured by enterprises using IoT produced an overwhelming flow of data that can be processed to create new products and services and more articulated competitive contexts. The different flows of information provide enterprises with a huge amount of data, which is growing exponentially every year (Kaisler et al., 2013). This boundless mass of growing information is found in the big data neologism which according to one of the most widely used definitions, referable to the McKinsey Report of 2011, defines big data as: "refers to dataset whose size is beyond the ability of typical database software tools to capture, store, manage and analyze" (Manyika et al., 2011) and are too complex to be processed with the normal software available to organisations and enterprises (Mayer-Schonberger and Cukier, 2013). The advantage of this definition is not to fix a numerical 'limit' of data volume where beyond this, one enters the big data dimension. It is at the crossroads between the volume of data and the ability to store and process it. As the volume of data increases, the capacity to store data and the speed of calculating needed algorithms for processing increases. Expanding the defining spectrum, Boyd and Crawford (2012), define big data as a cultural, technological and academic phenomenon resulting from the interaction of three elements: technology, analysis and mythology. Enormous datasets offer a higher form of intelligence and knowledge that can generate insights, previously impossible. The McKinsey report authors added the predictive element to the definition that shows to be one of the strategic variables most exploited by large companies. The triggering factor of big data phenomenon is the exponential growth of data production in terms of quantity and variety, as a result of a range of systems used for data collection combined with a drastic lowering of costs and volumes necessary to store data. Big data is usually defined by four Vs: volume, variety, velocity and value (Zikopoulos et al., 2012; Berman, 2013; Gantz and Reinsel, 2011) to which the fifth V (5Vs model) of 'veracity' was recently added (Bello-Orgaz et al., 2016). The exponential growth in data volume has forced the issuance of new units of measurement to be able to compute and quantify data. In big data, the unit of measurement is that of petabytes if not exabytes, while the zettabyte is used to measure the estimated volume of data produced annually in the world. In 2013, 4.4 zettabytes (trillion gigabytes) of data were produced annually. Estimates foresee for 2020, a volume of 40 zettabytes produced in a year, 300 times those collected in 2005. In the world, 16 million messages are exchanged every minute, 900 people enter Facebook and spend an average of 750 thousand dollars on e-commerce websites (Barlaam, 2018). One of the main benefits of organisations using big data is to create predictive models that are able to anticipate problems reaching to solutions that reduce future costs (Kim et al., 2014; Yiu, 2012).

Cloud computing especially offers SMEs that do not have the resources to create their own business intelligence (BI) with the possibility to make use of reliable resources of software, hardware, and infrastructure as a service (IaaS) delivered over the internet and remote data centres (Armbrust et al., 2010). It is considered a powerful technology to perform complex and large-scale computing operations without the need to maintain expensive computing hardware, dedicated space, and software (Hashem et al., 2015), and for this reason, it has been widely spread among organisations (Huan, 2013). However, three problems hinder its application:

1 a fear related to security in terms of data management for cybersecurity (Hipgrave, 2013; Lee, 2019)

2 the desire not to outsource information and strategic knowledge

3 the customisation of some of the processes belonging to a given company.

Digital data is present everywhere. It represents a valuable resource and opportunity for organisations and markets. Marketing professionals use it to direct advertising channels; production companies use it for machine learning for predictive maintenance and intelligent warehouse logistics; insurance services to optimise their offers; financial operators to interpret the market; and large distribution enterprises to optimise the arrangement of products and their traceability. However, the cost and risk to hold and retain such large amounts of data can make it a burden for many organisations (Cumbley and Church, 2013), as well as leading to the emergence of new computational and statistical challenges (Fan et al., 2014; Lv et al., 2019).

Big data and Industry 4.0 intersect each other in multiple areas facilitated by IoT. For example, collecting and elaborating different types of data from different instruments for example temperatures, pressure and vibrations enables the anticipation of malfunctions of a machine (Dobos et al., 2018), the so-called predictive maintenance. Or combining the economies of scale of homogeneous and mass production with extreme product differentiation, providing products that satisfy a single customer (Tamás, 2016) the so-called mass customisation. Other examples are ERP and SCM systems to manage the supply chain as a single production flow.

Given its disruptive importance and value, big data must be subject to government regulatory policies in terms of privacy and use of this same data by companies. But big data itself also offers a vast range of opportunities for the government itself, for example, it develops more precise predictive models to anticipate and regulate a country's economic dynamics, with implications for econometric models (Varian, 2014), which in turn improves services to companies and users, better manages fiscal and social programmes, implements decision-making models (Einav and Levin, 2014) and better understands the present and future needs of their citizens (Beresford, 2015; Desouza, 2014).

The data managed by simple computers present in organisations have become interacting flows that are managed by complex computer architectures, EIS, ERP and SMC. The process moved from data management to the production of data by objects and machines that interact with each other, producing goods and services, and opening up the era of IoT.

3 Methodology

This article is based on the selection of main contributions of academic literature on Industry 4.0 and big data policies. Extensive literature review of published academic articles was carried out, in addition to applied analysis. Main key issues that emerged from the literature review were compared with the operational reality of enterprises (mainly Italian enterprises), using results and insights pulled out from a research carried out by the research centre for economic studies Nomisma and Asterm[5] in 2018, which included a lengthy survey completed by 47 large organisations[6] concluded in May 2018 concerning the use of big data inside their organisation. In addition, qualitative considerations were taken from further direct interviews (16 interviews) completed in February 2019, on the theme of Industry 4.0 with leading companies in the Italian agro-industrial sector. The companies interviewed were of two types: leading companies in the region that use or produce big data and analytics and ICT companies that offer services related to big data. In addition, interviews with three out of the four universities located in the Emilia-Romagna region were conducted, particularly with supervisors of computer engineering courses.

On the other side, the United Arab Emirates Industry 4.0 and big data context was studied through the review of existing literature, analysis of official government publications and reports, policy analysis and strategic action plans.

If Industry 4.0 and big data that is associated with it are bringing wide attention and diffusion in literature, yet, its real application in companies is still, and at least in Italy and in the United Arab Emirate is in its start-up stage. Up till now, few companies can equip themselves with BI units, or make use of the potentials of cloud computing.

In order to investigate the limitations and potentials of big data, the authors of this study have chosen to analyse a dynamic, innovative and industrial regional context of the Emilia-Romagna region, in which the government has always played a major role in the advancement of enterprises. The Emilia-Romagna region is one of the most dynamic regions in Italy and Europe, and is characterised by a robust, highly innovative manufacturing structure in numerous sectors that represent excellence at European and world level. Four major universities are established on its territory, which are among the oldest in the world. At the inside of this region, its government designed its own identity of industrial policy based on innovation, pursuing a plan of development connecting science with industry, which since almost 20 years now had led to the emergence of ten technopoles on its grounds. A rare and perfect *milieu innovateur*, however, a number of obstacles are still present that slow down the potentials of big data and the enabling technologies connected to them. In parallel, the authors chose to study the case of the United Arab Emirates as it is similarly a dynamic and innovative context with a high presence of SMEs on its territory to that of the Emilia-Romagna region, however, reflects a different industrial and economic background. Although the economy of the UAE remains extremely reliant on petroleum, it has been successfully diversifying its economy in various non-oil high revenue producing sectors such as tourism and construction. Its manufacturing base is expanding in size and scope, including a wide range of products such as aluminium and metals, cement and ceramics, glass, and chemicals. The manufacturing sector as of the first half of 2015, contributed to 11% to the UAE's overall gross domestic product (GDP), with the aim to increase the contribution of the manufacturing sector to 20% by 2020 (U.S.-U.A.E. Business Council).

A comparison between the reality of Emilia-Romagna and the United Arab Emirates, will be useful to understand if different productive specialisations (of goods and services) and different local contexts, put in place different policies for the stimulation and diffusion of big data.

4 The role of the Emilia-Romagna Government

Big data is fairly a recent phenomenon, not only for the Emilia-Romagna region but also for the European Union. The importance of big data is recognised with the approval of the Horizon 2020 Program, within which several calls for proposals related to big data and artificial intelligence (AI) have been recently launched, and together with the integrated European supercomputing infrastructure allows the EU to be at the forefront at global level in the use of big data. This however calls for more dependency in the field of data economy and prevents European scientists and industries from processing their data outside the European Union.

This framework fits the emerging strategy on big data that the Emilia-Romagna region is trying to put in place. The regional big data ecosystem represents a unique setup in Europe, due to its possession of one of the most significant digital European infrastructures that is highly connected with university research entities. The big data community in this region consists of Cineca[7], five universities[8], the National Research Council (CNR)[9], three national institutes[10], and ENEA, a public Italian research entity that operates in the fields of energy and environment.

A favourable element for the development of the big data community is the presence of high-level academic and technological players which, combined with regional training policies, has enabled the launch of advanced training initiatives. The training aspect is judged as strategic to face one of the weaknesses of the system, which is the lack of human resources, specialised in disciplines related to big data and AI. For this reason, the Emilia-Romagna region has started the *Big Data Lab Project*, which has enabled the activation of 11 training courses, financed by the European Social Fund (ESF), which offer young graduate's key competences on potentials and applications of technological innovation and digitisation of information. The government of the Emilia-Romagna region has funded 17 doctoral scholarships in the area of digital economy and training activities are multiplying. For example, Bologna Business School has activated a Master degree in both Big Data Analytics, and Digital Technology Management and AI, while the University of Bologna has launched in 2017 a PhD in Data Science and Computation.

The regional government is aiding to create a favourable infrastructural environment for big data with the main goal of creating a critical mass combining research infrastructures characterised by international scientific and technological equipment; with international reputable research groups in three main sectors: supercomputing and big data; genomics, regenerative medicine and biobanks; and advanced materials and innovative production systems. Another initiative by the government is Project GARR-X aimed at the creation of a territorial digital infrastructure, which includes a new generation fibre-optic network, and a cutting-edge collaborative data environment for distributed storage system, which benefits the research community, universities and schools, and also public and private entities in the area. Garr-X Progress act as an enabling factor for existing or yet to be invented partnerships, carrying out research, and filling ICT infrastructure gap. Similarly, the newly established competence centre BI-REX which is expected to carry out a structured program of activities aimed at the creation of new products and processes (or improvement of existing ones) through the development and adoption of advanced technologies in the field of Industry 4.0. In this model, SMEs have the opportunity to be protagonists, drawing on technology, research and skills made available by universities, research centres and large economic players, enhancing characteristics of flexibility and craftsmanship through production models, and meeting the demands of new markets. BI-REX is expected to support companies throughout the country, providing them with training, advice and guidance related to the adoption of enabling technologies, and focusing mainly on connectivity, automation, advanced manufacturing and big data.

One central example of a place with an immense flow of data is that of the European Centre for Medium-range Weather Forecasts (ECMWF), which possesses the world's largest database of time-based numerical data. The centre currently based in Reading, UK, and chosen to be relocated to Bologna, Italy, serves to develop numerical methods for medium-range weather forecasts for the distribution to member states, and to develop scientific and technical research aimed at improving forecasts, and collecting and conserving meteorological data.

The presence of these infrastructures dedicated to big data ease the creation and accessibility of an open science platform and made available to both, the scientific community and the regional system, which is considered the most complex step. Main interventions made by the regional government are aimed at both strengthening human resource talents and creating a solid infrastructure that may cause indirect repercussions on the business world, and on large and medium-sized enterprises. More sophisticated and strategic intervention initiatives have been taken in this field, which involves financing agencies with the aid of the policy of attracting multinationals and large groups, the Regional Law 14/2014. This initiative promotes investments in the region, dedicated to Industry 4.0 and big data, IoT, AI, virtual and augmented reality. For example, Eon Reality, a Californian company that develops software and digital platforms in business, education and training areas received funding for the creation of an interactive digital centre, an Italian hub for the development of content and applications related to augmented virtual reality. Another example includes Sacmi, a historic cooperative in the Emilia-Romagna region in manufacturing machines and plants for the ceramic tile, packaging, beverage and quality control processes received funds for planning the creation of a research centre for the development of applications related to IoT. Start-up Energy Way of Modena is another company that received funds, which operates in the industrial data management sector, and developed innovative solutions for companies, through advanced mathematical models.

Companies currently engaged or trying to adopt big data shows weaknesses and some limitations. For some companies, the adoption of big data and the introduction of AI in their production processes has emerged with a certain 'ease', while for other companies, especially for small businesses, it shows unclear and difficult for such entities to understand how they can benefit from this 'regional system of big data', or how they can use the value of big data in their own activities. Therefore, there would be a need to start a 'training' entrepreneurial process on the potentials of big data, with increased enterprise awareness, deepened role of regional governments, and stronger collaborations with associations and groups. The next step involves facilitating easy access to big data and data analytics by SMEs, which represent the core of this new industrial revolution.

A comparison between the reality of Emilia-Romagna and the United Arab Emirates, will be useful to understand if different productive specialisations (of goods and services) and different local contexts, put in place different policies for the stimulation and diffusion of big data.

5 Survey results

5.1 The obstacles facing enterprises in the Emilia-Romagna region

Six reasons that hinder the spread of big data in these leading companies emerged from these interviews:

1 cultural obstacles widespread inside the organisation

2 scarcity of human resources with adequate skills

3 inadequate business dimension

4 difficulty of transforming potentials of big data into competitive market advantages, identifying specific targets for action

5 strategic secrecy of knowledge and confidentiality of data, which discourage intelligent data processing

6 difficulty of data access, open data and issues related to the new GDPR of May 2018.

5.2 The dimensional question

From the research carried out with the companies of the Emilia-Romagna region, a strong correlation emerged between the size of the company and the implementation of big data within the firm. Data analytics companies offering big data services are generally small-sized, while the groups (or companies) that are starting to demand big data and undertaking these challenges are few, and the largest in their respective business, and in the regional and national panorama.[11]

Big data therefore goes through a selective dimensional limitation between companies that can undertake this competitive challenge and those smaller companies, which are currently excluded. The companies interviewed, have estimated a period of at least five years before the realisation of economic returns from the investments undertaken towards big data, and 88% of these companies invested such amounts using their own resources, with no co-financing from any public body. The creation of an internal unit analytics heavily affects the share of turnover and consequently the marginality (EBTIDA). It also emerged that a range from 20 to 60 people are entirely dedicated to the collection, storage, data processing and development of AI algorithms. These professional figures usually involve computer scientists, physicists, mathematicians and engineers, many of which are PhD holders.

Table 1 Business function of departments benefiting the most of big data analytics

Production	18.18%
IT	36.36%
Business	54.55%
Marketing	27.27%
R&D	27.27%

Note: Companies that use or produce big data and analytics.

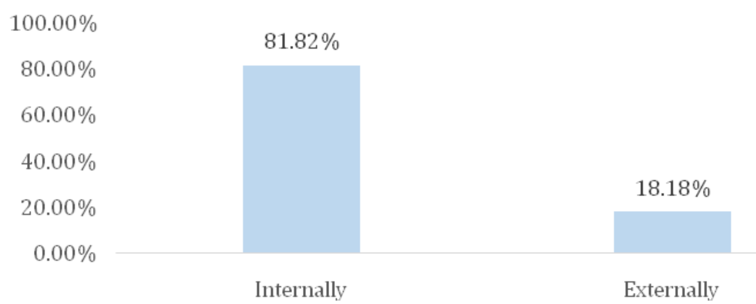
Source: Personal elaborations based on the 47 interviewed companies, May 2018

While Industry 4.0 has a wider range of applications and is more easily interconnected with adequate productive platforms, even medium-sized companies, and experience difficulty to access. From the interviews, Table 1 shows that only 18% use or benefit from big data in the production unit, and only 27% in the marketing and R&D units. The greatest expectations for the use of big data relies in the business unit (55%), in terms of developing completely new products and services that open up new markets for businesses. Therefore, the use of big data is seen as a radical innovation rather than incremental and therefore, more suited for larger organisations.

5.3 Indoor knowledge or outdoor knowledge?

The dilemma of narrow or shared knowledge is re-proposed in big data. If big data represents a strategic challenge in the next few years, it is understandable that companies have an undoubted advantage to guard their *secrets of knowledge* within their own walls. Researchers, breadth and transversality of knowledge to be governed, interoperability of data and collaborative manufacturing. Sharing of knowledge and databases with other companies would be marginal, if not absent. Figure 1 shows that not only most data is processed and analysed internally (82%), but most of the data is also shown to be produced internally (67%), only a third of the data (33%) comes from outside (see Table 2).

Figure 1 Data analysis and processing by companies demanding big data (see online version for colours)



Source: Personal elaborations based on the 47 interviewed companies, May 2018

Table 2 Data production mode

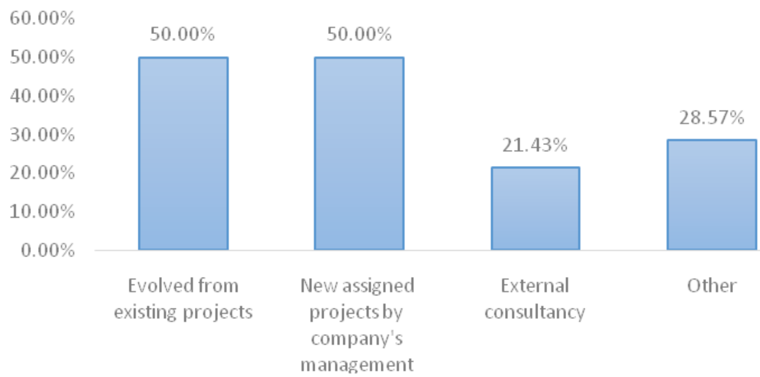
	Internal	*Internal and external*
ICT companies that offer big data services	58.33%	41.67%
	Internal	*External*
Companies that use or produce big data	66.67%	33.33%

Note: Companies that use or produce big data and analytics and ICT companies that offer services related to big data.

Source: Personal elaborations based on the 47 interviewed companies, May 2018

In the case of big data, the collaborative mechanism that originated and characterised the industrial districts and business clusters in Italy have been clearly disrupted. In fact, as seen in Figure 2, most of the big data projects in the companies interviewed have evolved from existing projects (50%) or from the IT department of the company (50%). Only 21% of the companies requested support from external consultancy agencies. Of these companies, 64% did so for the development of software and platforms while only 18% for the creation of strategic projects.

Figure 2 Data production mode (see online version for colours)



Note: Companies that use or produce big data and analytics and ICT companies that offer services related to big data.

Source: Personal elaborations based on the 47 interviewed companies, May 2018

The Italian situation differs from the US model. US giants pursue different philosophies: some vote more towards *outdoor knowledge*; while others rigidly embrace the *indoor knowledge*. Companies such as Microsoft and IBM invest heavily in research in AI and their researchers publish numerous articles. They usually do not require their researchers to forcefully apply their findings to business activities (*The Economist*, 2018). At the extreme opposite, there are economic giants such as Apple and Amazon, where research is strongly market oriented and business solutions are expected from the work of their researchers. In the middle, we can position Google and Facebook where their researchers, although having to engage in business oriented research paths, have some degrees of freedom and sharing of research.

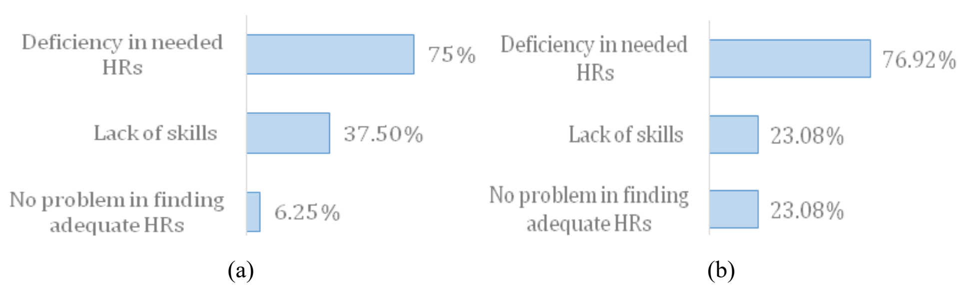
A trade-off is created between the need for company secrecy and the need for personnel recruitment that is scarcely present in the market. Companies that allow their researchers to share research paths externally, exerting less pressure on economic expectations of results, will be more likely to attract talent. External sharing of research results leads to greater career opportunity for the researcher and therefore, can be a condition that makes most competent resources carefully evaluate their decision before signing any work contract. The conflict between the opening and closure of research results also involves Chinese giants such as Baidu, which in 2013 opened two research laboratories in the Silicon Valley focusing on AI. Western researchers evaluate them very positively, but still prefer to work for the US giants, partly because of their relative transparency (*The Economist*, 2018).

5.4 Specialised skills: a scarce and desirable resource

One of the main obstacles that hinder the expansion of the intelligence units inside and outside enterprises in regional and national territories is the lack of human resources specialised in disciplines related to big data and AI. The appearance of big data in the economic landscape has generated rising competition among companies in their mission to ensure sufficient number of researchers and graduates with appropriate skills, a resource which suddenly have become rare and precious. In the field of big data, job offerings have grown so quickly driven by the sum of two effects that can be defined as the *expansion effect* and the *enlargement effect*. The first effect is attributable to the growth in the supply of job offerings by companies, operating in production sectors that are already using and requiring such skills (computer engineers, physicists, etc.), which are driven by the potentials of big data and decided to upgrade their data analytics unit and research team. The enlargement effect describes a new phenomenon. It involves companies in sectors that historically never used such human resource skills, as for example, the insurance, distribution or financial sectors, which now demand specialised skills to manage the huge amount of data they own, especially in the processing phase. Human resources that were previously demanded only by companies in adjacent sectors are now found to be attractive for companies of any economic, productive and service sector.

Looking at Figure 3, it emerges how finding suitable human resources is of severe concern and is present in both companies, those who demand big data and in those who offer big data related services. 77% of the companies interviewed who demand big data argued about the difficulty of finding the necessary human resources in the Italian market in order to develop big data, and to increase the number of their data scientists or size of their data analytics unit. The question is strictly numerical since only 23% of production companies or companies demanding big data discussed about lack of training or possession of specific skills. In other words, universities adequately train individuals with the correct and required skills for the needs of businesses, but they are numerically insufficient in meeting the rapid demand of companies that develop big data.

Figure 3 (a) ICT companies (b) Companies demanding big data (see online version for colours)



Source: Personal elaborations based on the 47 interviewed companies, May 2018

The major deficiency manifests in particular in the case of the use and design of AI. The competition on big data will be subject to data possession, immense data warehouses of personal data combined with powerful machines with enormous computing capacity. However, on the side of AI, it will be the distinctive competences of human resources to decree its victory. The companies interviewed are aware of the strategic importance of ensuring adequate human resources, possibly the best in the market. From the interviews, it emerged that the professional skills required related to big data are mostly data scientists (45%), IT executives (23%), physicists and mathematicians (18%), business analysts (9%) and engineers (5%). Training offerings in the region are robust and of high quality level, but insufficient for the needs of today's competitive environment. Although all four regional universities have a three-year undergraduate program, master degree programs in computer engineering, and degree courses in mathematics and physics, however, the sum of these graduates is not sufficient to meet the demands of companies, who are facing competition to secure such resources as soon as they graduate. All the companies interviewed agreed that the lack of specific skills is one of the biggest obstacles to the development of big data in their company.

The mismatch between demand and supply of skills represents a significant negative social impact. An important part of employment with high added value is lost and the competitiveness of companies is weakened as adequate human resources are of fundamental strategic value to big data. Spaces for government policy actions are essential to increase the competitiveness of companies in the rising competition towards big data.

6 Context analysis: Industry 4.0 and big data, United Arab Emirates

Over the past nearly 50 years, the United Arab Emirates took a giant leap in the global arena as a major economic player with a GDP of 382.6 billion dollars and per capita $67,700. This 9.3 million young nation, with over 80% foreign workforce, one of the highest levels of immigration in the world, is currently engaged in massive efforts towards the diversification of its economy, which was once highly dependent on its own oil, with exception of the city of Dubai. While, Abu Dhabi, the capital, on the other hand, holds 9% of the world's oil reserves and 5% of the world's gas reserves.[12] The diversification in the country's economy becomes central as the International Monetary Fund estimated that just under a third of the UAE GDP comes from oil. This is planned to fall to 20% by 2021, and then 0% in the next 50 years (British Council, 2018).

The UAE has realised the importance of big data and the value of this immensely growing information flow is limited without the creation of the wider infrastructure to support it. The UAE has transitioned from *e-government* to *m-government* and now diving into its initial phases of smart government. The *m-government* success rate achieved 96% in 2015. The ongoing following stage is linking all the services together, improving functionality of smart services. The national economy is advancing rapidly. According to the *World Competitiveness Yearbook 2018*, the UAE is the only country in the region to be among top 10. It recorded the seventh most competitive nation globally, going up three ranks compared to the previous year, and 28 positions in seven years, outperforming many advanced economies such as Norway, Canada and Sweden. Key engines of the national economy come from its SMEs.

It is documented that some leading enterprises started making strategic investments to use emerging technologies such as big data, however, major investments in this field remains to be demanded and used by the largest organisations in the territory, especially in sectors of oil and gas, retail, hospitality, travel and finance. However, more and more entities from a wider range of diverse sectors started understanding the potentials of big data and the economic value connected to it. Investments in enabling technologies such as big data become vital as they operate in a country where data is growing exponentially. The UAE has one of the highest internet penetration in the world. It was found that more than 99% of the population of the UAE had broadband connections as of November 2018.

Taking into consideration the case of the city of Dubai, the launch of the Dubai Data Law in October 2015 has marked the first most central pillar regulating data dissemination and exchange in the Emirate of Dubai. Open data becomes increasingly of value when developing smart cities. This law allowed for the opening and sharing of data. Dubai open data is defined as any Dubai data that is published and can be downloaded, used and reused without restrictions by all types of users, while shared data is the data that has been classified as either confidential, sensitive or secret. It can only be accessed by other government entities or by other authorised persons. The law allows the opening and sharing of some private sector datasets by 2021 promoting the creation of innovative products and services. The implementation of this initiative included policy related programs including developing the regulatory framework, Dubai Data Manual, technical infrastructure, readiness within government entities, and consultation with the private sector.

As part of the birth of Industry 4.0, the UAE is vastly investing in advanced technologies such as software, big data, AI, virtual reality, and IoT that help in transforming the face of production, leading towards greater efficiencies and alteration of the relationship between humans and machines. For instance, Mubadala Investment Company, an Abu Dhabi global investment government-owned company has developed from its original platform as a petroleum company into a diversified investment firm. Some initiatives undertaken include creating partnerships in advanced technology and high-value industries in key sectors, and most recently, signing an agreement with *IBM Watson* technology to build an ecosystem of partners and developers. In addition, over the past two years, the country launched the UAE Strategy for the Fourth Industrial Revolution (4IR) and UAE Strategy for AI, appointing the world's first AI minister. A study reported that AI is estimated to contribute 14% of 2030 GDP according to PwC Middle East (2018). This contribution is similar to the contributions estimated for economies in Southern Europe and Developed Asia (PwC Middle East, 2018). The government is furthermore focusing to become the first blockchain powered government in the world aided by the launching of the Emirates Blockchain Strategy 2021 that aims to capitalise on the blockchain technology to transform 50% of government transactions into the blockchain platform by 2021. This includes robot police, flying taxis and driverless vehicles on its roads. By adopting this technology, the government expects to save approximately three billion dollars in transaction documents annually. It is estimated that AI will also cut government work cost by 50%, due to less reliance on the use of paper in transactions. UAE Government is also playing key role in digital transformation, expecting the generation of nearly nine billion dollars in 2021. IoT estimate amounts to five billion dollars by 2020 and open data to add three billion dollars to Dubai's GDP by 2021, while blockchain technology in public services will add around 1.5 billion dollars by 2020 according to Smart Dubai (2016) Office. The country started observing some benefits of their investments in highly advanced technologies. For instance, industrial investments of the value of 27 billion dollars invested in Abu Dhabi led to the presence of more than 600 factories and manufacturing facilities. In addition, the emirate is currently producing aerospace products for Boeing and Airbus planes (United Arab Emirates Ministry of Economy, 2015).

The UAE recently witnessed some major shifts in business models in that of the banking and finance sectors, where many of the traditional jobs have been automated and replaced by some form of AI. For example, the Emirates NBD Bank virtual assistant is the first in the MENA region and one of the few in the world who can converse with customers naturally. In addition, the UAE is becoming a top hub for fintech start-ups, supported by increased funding by the government and initiatives taken by the financial free zones in both Dubai and Abu Dhabi. However, the so far known investments in big data seem to remain being produced and utilised by some of the largest organisations only. For example, Majid Al Futtaim Group and Dnata Travel announced plans to enhance their advanced analytics capabilities to uncover valuable consumer insights. In addition, Emirates transformation initiative launched in 2015, explores big data, predictive analytics, AI, machine learning and robotics, and aimed at re-inventing business processing and reinforcing decision-making using big data and real time business analytics. Some of these large enterprises have already created their own data analytic units for data enrichment and production.

On the other side, private sector companies in various new sectors such as media, insurance, retail and healthcare, started adopting strategic measures in big data analytics to help understand their clients and offering personalised services to enhance customer satisfaction (Zawya, 2018). The so-called *enlargement effect*, a new phenomenon that starts involving more and new sectors of any economic, productive and service sector invest in this field.

7 Action plans analysis: infrastructural challenges, United Arab Emirates

The UAE Government has invested massive amounts into big data and Industry 4.0 initiatives, however, it is yet early for actual benefits generated to be known. It is certain that the government requires sophisticated infrastructure to support such emerging technologies as mining tools, BI applications, and server and network infrastructure (Deloitte, 2015). Although the UAE ranked highest among the Middle East countries in Open Data Barometer, it has still a low rank globally at 59th position (The World Wide Web Foundation, 2017). This global measure assesses how governments are publishing and using open data for accountability, innovation and social impact.

The government started addressing some challenges faced particularly related to blockchain initiatives. For instance, the Government of Dubai is partnering with international bodies such as UK start-up ObjectTech to bring blockchain-based security at Dubai International Airport, developing digital passports and eliminating manual checks. In addition, Dubai Customs and Dubai Trade are currently testing blockchain for trade finance in partnership with IBM. However, an increasing role of government is needed to discover actionable insights from the wealth of data. The main advantage that big data technologies offer is their capability of merging different types of data, mining them for insights, and combining them for actionable insights (IBM, 2015). Due to the growing youth population of the Middle East, this region is expected to observe one of the highest growth rates in mobile phone traffic, volume of text, photo, audio and video transferred by smart devices to reach nearly 4.3 exabytes by 2020, 15 times the current volume (MEED, 2018). Therefore, increased investments in infrastructure need to be in place to fully exploit Industry 4.0 and big data technologies. For instance, AI requires huge computing power that not all UAE businesses can afford, considering that the majority of these companies are of a small and medium-sized dimension, making their exploitation or ability to invest in such technologies highly limited, or possibly completely excluded. Simultaneously, complexity issues of big data may arise. For example, the Dubai data initiative has been launched with a clear definition of Dubai data, opening and sharing, however, not all organisations will be willing to change their organisational culture, or giving away their data for free due to privacy concerns. Complexity is much more significant than volume or variety. Complexity creates conditions for structural data silos which together with skill gaps may stop local governments in exploiting big data to its full potential. Continuous efforts in handling big data and learning insights from it become essential, and successfully embedding such technologies into decision-making processes in both public and private sectors.

7.1 UAE Government, building pool of desired skilled workforce

As the UAE economy grows, more local talents of skilled professionals are increasingly in demand, leading to new types of job descriptions in both private and public sectors. Industry 4.0 requires highly skilled individuals, especially with STEM skills.[13] Even though STEM graduates are increasing in the UAE and the number of women STEM students at UAE universities have surpassed global averages with more than 50% than in countries such as the UK, Canada, Germany and France according to reports by Times Higher Education, these numbers may either still be considered not enough or some may be left not fully utilised upon graduation due to socio-cultural barriers. Recent initiatives aiding the readiness and building pool of skilled resources include the role of public funded universities across the country. For example, the Higher Colleges of Technology, recently launched Bachelor degree programs in *Business Analytics*, and operating under the theme *HCT 4.0 – Employability and Beyond*, with a focus on upskilling, entrepreneurship and life-long learning, which will enable the institution to graduate hi-tech companies and technical leaders (HCT, 2019).

Furthermore, the ongoing National Employment Strategy 2031 initiative is currently helping in building pool of skilled human resources, and seeking to increase Emiratisation rates in value-added economic sectors. The UAE Government is also increasing the number of personnel in R&D and promoting innovation and entrepreneurship programs. In fact, the time required to start a business in the UAE has been reduced by 80% in the last ten years, going down from approximately 18 days in 2008 to less than four days in 2018 (World Bank, 2018). Yet, the competition for adequate skilled human resources is on the rise, requiring increased role of government in building pools of Industry 4.0 talents. In March 2017, His Highness Sheikh Mohammed bin Zayed, Crown Prince of Abu Dhabi and Deputy Supreme Commander of the UAE Armed Forces, mentioned in front of over 3,000 UAE youth: "You are no longer competing amongst yourselves, but with the greatest minds around the world."

Industry 4.0 and big data are pushing many repetitive jobs to become completely automated. This led to the emergence of a structural shift in the increased demand for highly technical skills such as data scientists that did not exist some years ago. Other challenges research shows that a large number of Emirati students prefer to study abroad for their higher education. Data reveals that about 91% of Emirati students in higher education in the USA are male and with 45% of them enrolled in STEM fields. As per data published by *Forbes*, the countries with most STEM graduates are China, followed by India, the USA, Russia, Iran consequently (2016). Increased technology, globalisation, connectivity and mobility has already created UAE workforce highly diversified and one of the highest in the world with share of foreign workforce. The challenge will continue creating even a higher level of competition as Industry 4.0 reality nurtures increasingly virtual work, representing the rise of a more complex competition that UAE youth and UAE-based foreigners will face against global workforce in key technologies, such as data governance, BI, data analysis, data storage, data processing and data aggregation. A study from Oxford University suggested that 47% of current jobs could be automated and replaced by robots in the next decade or two (Oxford Martin School, 2018). In parallel, in Australia, a recent report commissioned by the Foundation for Young Australians estimated future workplaces, where 40% more time will be spent on critical thinking, 77% more time using science and mathematics skills, and time spent in management will fall by 26%. Providing youth with future skills is one major challenge. Continuous and consolidated efforts with private sector should be an integral part in this process. This will also help employers reduce unneeded entry level job vacancies due to lack of skills, leading to higher efficiencies and productivity in the UAE economy as a whole.

8 Discussion and conclusions

Review of literature and survey findings showed how big data is the fulcrum of the broader economic and social revolution that takes the name of Industry 4.0. Like all paradigms, characterised by radical innovations rather than incremental. The use of big data and data analytics, despite having recorded significant growth rates, there is a struggle that Italian companies face in order to adapt to these new competitive challenges. From the survey and the direct interviews conducted, there are five obstacles that slow down or prevent the spread of big data in production and service sectors: the size of companies, human resources, the lack of sharing of knowledge (internalisation of knowledge), the absence of a common language (standardisation of data storage protocols), and open data. The transformation of these disruptive innovations into new competitive opportunities is not trivial. It emerges that market forces alone are insufficient to develop big data in companies, and especially in this new era of global competition. Even though the economy is rapidly advancing in Industry 4.0 and big data technologies, the adoption of such technologies are by the few leading and largest organisations, and therefore, the biggest challenges remain facing mostly the SMEs. Therefore, the role of government becomes crucial in removing these obstacles and elaborating industrial and technological policies towards the enhancement of a dynamic ecosystem were data can flow more smoothly along the production chain.

The UAE scenario takes a similar pattern, taking a comparable productive structure in terms of number and dimension of its widely spread SMEs on its territory. However, the approach of Industry 4.0 is different: the Italian approach (European approach) is oriented towards manufacturing, while the United Arab Emirates is more oriented towards services (can be slightly considered similar to the US approach). For this reason, some obstacles and challenges to the dissemination of Industry 4.0 technologies are common to the two countries, while others weigh differently.

First of all, the challenge of building adequate human resources remains one main and common obstacle in both countries studied. However, the solutions are partly different. Italy requires a stronger connection between its resources dedicated towards big data and the specifics and peculiarities of the country's industrial fabric, therefore, needed actions are more concentrated towards building a stronger connection and development between the territory's internal resources and in stimulating the educational and training programs of universities. In the case of the United Arab Emirates, although government efforts highly invest in strengthening its public educational system and promoting innovation and entrepreneurship action plans across, the level of Emiratisation[14] of such resources upon graduation is yet low in the private sector, relying on continuously stimulating the flow of appropriate expertise from abroad. Secondly, in Italy, the greatest effort towards big data is to find a connection and application with industry. Therefore, the role of government is to stimulate a closer connection between science and industry with the help of co-financing of joint research programs. In the case of the United Arab Emirates, big data is currently mainly focused towards the enhancement of the services of the public administration in its smart transformation journey. The UAE further requires to enrich interactions between academia, industry and government to foster the growth potential of enterprises and the evolution of their research relations with the research world. Thirdly, the issue of secrecy and confidentiality of processed data, which slows down or inhibits the use of cloud computing involves both countries. While in the United Arab Emirates' focus is on regulating the privacy of data and its use, while in the Italian case, the problem focuses mainly on the secrets of manufacturing. The fear, on the part of the Italian companies is that if outsourcing their elaborations, and consequently their strategies, they can be used by competing companies. For this reason, almost all the companies surveyed internalised the processing of data in their own BI units. Fourthly, the obstacle of diverse languages and therefore the desirability of a common language are experienced in a different way. In Italy, the value chain and the different stages of interoperability within the transformation and delivery stages of the product are more hampered. In the United Arab Emirates, it more involves the dialogue between government, businesses and citizens. Fifthly, open data and data regulation covers both countries. Italy is subject to the GDPR (EU) which came into force in May 2018. While the legislation protects European citizens, however, it also creates a competitive asymmetry for data acquisition for European companies competing in a global market. The UAE does not have a comprehensive data protection law at its federal level, however, there are a number of laws in place that regulates privacy and data security. The UAE also has certain data protection laws that are specific to certain sectors. For example, the recent issued Federal Law No. 2 of 2019 to protect the use of information technology and communications (ITC) in the healthcare sector and restricting data to be transferred outside the country (DHA, 2019). This may particularly affect cloud-based health solutions who are involved in the collection, storage and processing of health data. At emirate level, Dubai Law No. 26 of 2015 intends to create a framework to facilitate and encourage the sharing of data between government and the private sector making that information open data. Sixthly, cultural obstacle is found in both countries. Industry 4.0 is a disruptive innovation. Very different from the previous 'Industry 3.0', which represented the use of electronics and IT to further automate production and was in 'continuity' with the previously accumulated know-how. Industry 4.0 redefines production platforms, value chains, action and planning models, and competitive contexts making a complete break with the past. For this reason, entrepreneurs are held back by a mixture of mistrust and lack of information. Here, the space for government action is ample. Appropriate information and diffusion of the culture of innovation (particularly enabling technologies) will have a decisive impact on the future competitiveness of the country.

Finally, although Italy and the United Arab Emirates use two approaches to Industry 4.0 of different matrix, with the first more oriented towards manufacturing and the second towards services, over time these differences will go to fade away. The future of Industry 4.0 and the connected use of big data that is related to it is interoperability. Therefore, the boundaries between production and services will weaken and production will be primarily the management of a single flow of knowledge: from raw materials to services to the customer.

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Notes

1 Germany and Italy possess world leading manufacturing systems.

2 In Europe, there are around 23 million SMEs which represent 99% of all EU businesses. 92% of these are micro businesses with less than ten employees.

3 Regulation (EU) 2016/679 of 27 April 2016 concerns the protection of individuals with regard to the processing of personal data, as well as the free circulation of such data. The regulation took effect 25 May 2018.

4 For example, the request for consent for the collection and processing of personal data cannot be ambiguous. People can request a copy of the data in their possession (data portability), request to correct the information (right to rectification) and request the cancellation of their data (right to be forgotten).

5 For the analysis of big data in companies situated in the Emilia-Romagna region, reference is to a recent field research coordinated by one of the authors of this article together with Dr. Concetta Rao from Nomisma: Poma L. Rau C., Big Data in Emilia Romagna, carried out by Nomisma for Aster, Bologna, June 2018. In conducting the research, 47 interviews were completed.

6 The selection of enterprises involved all the companies that in recent years have participated in research projects related to big data, or have participated in focus groups of European projects on this topic or have obtained funding to develop data analytics.

7 Cineca is a not-for-profit consortium, made up of 67 Italian universities, nine Italian research institutions, one polyclinic and the Italian Ministry of Education. It is the largest Italian computing centre, one of the most important worldwide. With more than 700 employees, it operates in the technological transfer sector through high performance scientific computing, the management and development of networks and web-based services, and the development of complex information systems for treating large amounts of data.

8 University of Ferrara, Alma Mater Studiorum – University of Bologna, University of Parma, University of Modena and Reggio Emilia, and University La Cattolica of Piacenza.

9 CNR is the largest public research facility in Italy with about 4,000 researchers.

10 The National Institute of Nuclear Physics (INFN), the National Institute of Astrophysics (INF), and the National Institute of Geophysics and Volcanology (INV).

11 To give an order of magnitude, the turnovers (achieved in Italy) of the main groups interviewed by sector of reference are the following. Turnover of around 1.4 billion euros for the advanced mechanical engineering group, with over 5,000 employees (half of which abroad), 22.5 billion turnover for the insurance and financial group, with over 15,000 employees. Turnover of 14.5 billion euros for the group that operates in the large-scale organised distribution, with over 53,000 employees.

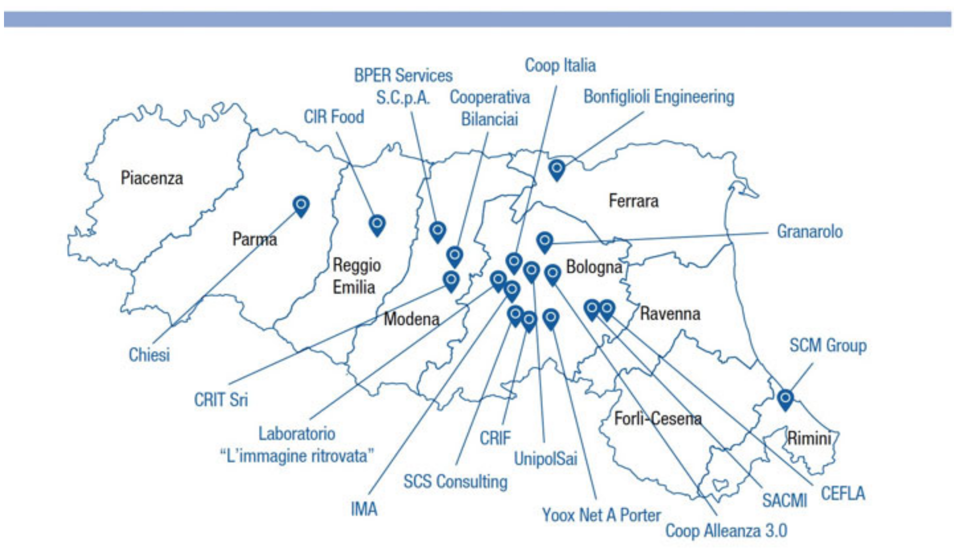
12 Mubadala, a wholly owned investment vehicle of the Government of Abu Dhabi established in January 2017 as a public joint stock company, merging the Mubadala Development Company and the International Petroleum Investment Company.

13 STEM: science, technology, engineering and mathematics.

14 The UAE Government launched the Emiratisation (Tawteen in Arabic) campaign which mandates the inclusion of Emiratis in the job sector, particularly in the private sector.

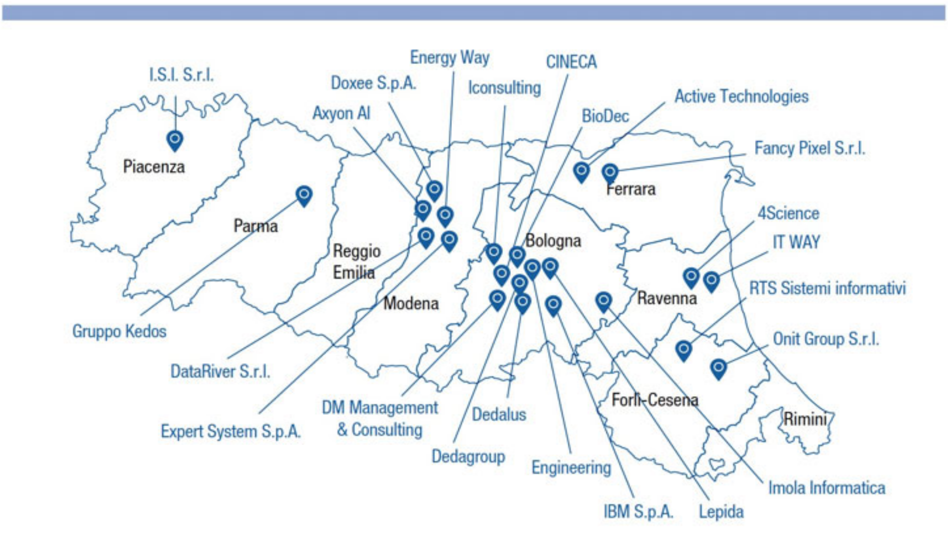
Appendix 1

Figure A1 Location of companies in the Emilia-Romagna region that use of produce big data (see online version for colours)



Appendix 2

Figure A2 Location of ICT companies in the Emilia-Romagna region that offer services related to big data (see online version for colours)



Appendix 3

Table A1 Questionnaire framework designed for companies providing services related to big data

General company information
• Company name • Business sector • Year of commencement of activity • Name and role of interviewee
Section A – company positioning and innovation actions
• Company turnover • Number of employees • Percentage of employees by qualification degree • Turnover trend, investments, occupation, exports • Innovation activities in the last three years • Modality of innovative processes • Planning for innovation investments in the next two years

Table A1 Questionnaire framework designed for companies providing services related to big data (continued)

Section B – elements related to the use of big data
• Strategic goals the company aims to reach using advanced techniques of data analysis
• Actual achievement of goals in the last three years
• Presence of obstacles in reaching goals
• Impact and result of the introduction of data analytic techniques in business processes
• Business function or area that mainly benefited most from big data analytics
• Level of adoption and use of big data technologies
• Quantity of data production and velocity of data production
• First project related to big data
• Channels used to activate initial projects
• Internal and external organisation for the utilisation of big data
Section C – indications on the professional figures specialised in data analytics
• Professional figures and required competencies for the development of big data analytics
• New recruitment programs
• Difficulties in finding required professional figures
• Planned training activities
Section D – other information related to the use of big data
• Average annual budget for activities related to big data
• Financing method
• Connections with other companies related to the use of big data
• Connections with educational institutions/universities
• Connections with international institutions/bodies for conducting educational and developmental activities
• Policy interventions to strengthen the adoption of technologies and processes related to big data
• Needed support from institutions to strengthen innovation activities

Appendix 4

Table A2 Questionnaire framework designed for ICT companies in the Emilia-Romagna region that offer services related to big data

General company information
• Company name
• Business sector
• Year of commencement of activity
• Name and role of interviewee

Table A2 Questionnaire framework designed for ICT companies in the Emilia-Romagna region that offer services related to big data (continued)

Section A – company positioning and innovation actions
• Company turnover • Number of employees • Percentage of employees by qualification degree • Turnover trend, investments, occupation, exports • Innovation activities in the last three years • Modality of innovative processes • Planning for innovation investments in the next two years
Section B – elements related to the use of big data
• Type of consultancy/service offered • Customer location • Level of adoption of technologies related to big data • Level of use of technologies related to big data • Professional figures/skills used • Number of full time staff • Origin of the people employed • Information about customers concerning big data projects
Section C – indications on the professional figures specialised in data analytics
• Professional figures and required competencies for the development of big data analytics • New recruitment programs • Difficulties in finding required professional figures • Planned training activities
Section D – other information related to the use of big data
• Average annual budget for activities related to big data • Financing method • Connections with other companies related to the use of big data • Connections with educational institutions/universities • Connections with international institutions/bodies for conducting educational and developmental activities • Policy interventions to strengthen the adoption of technologies and processes related to big data • Needed support from institutions to strengthen innovation activities