The European Big Data Value Ecosystem

Edward Curry, Andreas Metzger, Sonja Zillner, Jean-Christophe Pazzaglia, Ana García Robles, Thomas Hahn, Laure Le Bars, Milan Petkovic, and Nuria De Lama

Abstract The adoption of big data technology within industrial sectors facilitates organizations to gain competitive advantage. The impacts of big data go beyond the commercial world, creating significant societal impact, from improving healthcare systems to the energy-efficient operation of cities and transportation infrastructure, to increasing the transparency and efficiency of public administration. In order to exploit the potential of big data to create value for society, citizens and businesses, Europe needs to embrace new technology, applications, use cases and business models within and across various sectors and domains. In the early part of the 2010s, a clear strategy centring around the notion of the European Big Data Value Ecosystem started to take form with the aim of increasing the competitiveness of European industries through a data ecosystem which tackles the fundamental elements of big data value, including the ecosystem, research and innovation, business,

E. Curry (✉)
Insight SFI Research Centre for Data Analytics, NUI, Galway, Ireland
e-mail: edward.curry@nuigalway.ie

A. Metzger
paluno, University of Duisburg-Essen, Duisburg, Germany

S. Zillner
Siemens AG, Munich, Germany

J.-C. Pazzaglia
SAP, Mougins, France

A. García Robles
Big Data Value Association, Bruxelles, Belgium

T. Hahn
Siemens AG, Erlangen, Germany

L. Le Bars
SAP, Paris, France

M. Petkovic
Philips and Eindhoven University of Technology, Eindhoven, the Netherlands

N. De Lama
Atos, Madrid, Spain

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policy and regulation, and the emerging elements of data-driven AI and common European data spaces. This chapter describes the big data value ecosystem and its strategic importance. It details the challenges of creating this ecosystem and outlines the vision and strategy of the Big Data Value Public-Private Partnership and the Big Data Value Association, which together formed the core of the ecosystem, to make Europe the world leader in the creation of big data value. Finally, it details the elements of big data value which were addressed to realise this vision.

Keywords Data ecosystem · Big Data Value · Data innovation

1 Introduction

For many businesses and governments in different parts of the world, the ability to effectively manage information and extract knowledge is now seen as a critical competitive advantage, and many organisations are building their core business on their ability to collect and analyse information, to extract business knowledge and insight (Cavanillas et al. 2016a). The capability to meaningfully process and analyse large volumes of data (big data) constitutes an essential resource for driving value creation, fostering new products, processes and markets and enabling the creation of new knowledge (OECD 2014). The adoption of big data technology within industrial sectors facilitates organisations in gaining competitive advantage. The impacts of big data go beyond the commercial world, creating significant societal impact, from improving healthcare systems to the energy-efficient operation of cities and transportation infrastructure, to increasing the transparency and efficiency of public administration.

Europe must exploit the potential of big data to create value for society, citizens and businesses. Europe needs to embrace new technology, applications, use cases and business models within and across various sectors and domains (Cavanillas et al. 2016b). A clear strategy was needed to increase the competitiveness of European industries through a data ecosystem which tackled the fundamental elements of big data value, including the ecosystem, research and innovation, business, policy and regulation, and the emerging elements of data-driven AI and common European data spaces. This chapter describes the notion of big data value and its strategic importance. It details the challenges of creating a European Big Data Value Ecosystem, and outlines the vision and strategy of the Big Data Value Public-Private Partnership (BDV PPP) to make Europe competitive in data technologies and the extraction of value from data. Finally, it details the elements of big data value which were addressed to realise this vision.

In what follows, Sect. 2 aims to define the notion of big data value. Section 3 elaborates on the strategic importance of big data value for Europe. Section 4 summarises the process that was followed in developing a European big data value ecosystem. Section 5 drills down into the different elements of this ecosystem, along which the remaining chapters of this book are structured.

2 What Is Big Data Value?

In recent years, the term "big data" has been used by various major players to label data with different attributes (Hey et al. 2009; Davenport et al. 2012). Several definitions of big data have been proposed over the last decade (see Table 1).

Big data brings together a set of data management challenges for working with data under new scales of size and complexity. Many of these challenges are not new. What is new are the challenges raised by the specific characteristics of big data related to the 3 Vs:

- **Volume (amount of data):** dealing with large scales of data within data processing (e.g. Global Supply Chains, Global Financial Analysis, Large Hadron Collider).
- **Velocity (speed of data):** dealing with streams of high-frequency incoming real-time data (e.g. Sensors, Pervasive Environments, Electronic Trading, Internet of Things).
- **Variety (range of data types/sources):** dealing with data using differing syntactic formats (e.g. Spreadsheets, XML, DBMS), schemas and meanings (e.g. Enterprise Data Integration).

The 3 Vs of big data challenge the fundamentals of existing technical approaches and require new forms of data processing to enable enhanced decision-making, insight discovery, and process optimization. As the big data field has matured, other Vs have been added, such as Veracity (documenting quality and uncertainty) and Value (Rayport and Sviokla 1995; Biehn 2013). The definition of Value within

Table 1 Definitions of big data (Curry 2016)

Big data definition	Source
"Big data is high volume, high velocity, and/or high variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization."	Laney (2001), Manyika et al. (2011)
"When the size of the data itself becomes part of the problem and traditional techniques for working with data run out of steam."	Loukides (2010)
Big data is "data whose size forces us to look beyond the tried-and-true methods that are prevalent at that time."	Jacobs (2009)
"Big data is a field that treats ways to analyse, systematically extract information from, or otherwise deal with data sets that are too large or complex to be dealt with by traditional data-processing application software."	Wikipedia (2020)
"Big Data is a term encompassing the use of techniques to capture, process, analyse and visualize potentially large datasets in a reasonable timeframe not accessible to standard IT technologies. By extension, the platform, tools and software used for this purpose are collectively called 'Big Data technologies.'"	NESSI (2012)
"Big data can mean big volume, big velocity, or big variety."	Stonebraker (2012)

Table 2 Definitions of big data value

Big data value definition	Source
"Top-performing organizations use analytics five times more than lower performers...a widespread belief that analytics offers value."	Lavalle et al. (2011)
"The value of big data isn't the data. It's the narrative."	Hammond (2013))
"Companies need a strategic plan for collecting and organizing data, one that aligns with the business strategy of how they will use that data to create value."	Wegener and Velu (2013)
"We define prescriptive, needle-moving actions and behaviors and start to tap into the fifth V from Big Data: value."	Biehn (2013)
"Data value chain recognizes the relationship between stages, from raw data to decision making, and how these stages are interdependent."	Miller and Mork (2013)

the context of big data also varies. Table 2 lists a few of those definitions, which clearly show a pattern of common understanding that the Value dimension of big data resets upon successful decision-making through analytics. The value of big data can be described in the context of the dynamics of knowledge-based organizations, where the processes of decision-making and organizational action are dependent on the process of sense-making and knowledge creation (Choo 1996).

3 Strategic Importance of Big Data Value

Economic and social activities have long relied on data. But the increased volume, velocity, variety and social and economic value of data signals a paradigm shift towards a data-driven socio-economic model. The significance of data is continuing to grow in importance as it is used to make critical decisions in our everyday lives, from the course of treatment for a critical illness to safely driving a car. The exploitation of big data in various sectors has already had a significant socio-economic impact. According to International Data Corporation (IDC),[1] the global investment in AI and Big Data is projected to reach 86.6 billion euro worldwide in 2023, whereas the European share of industrial investments for this market is estimated at 18.8 billion euro. Since 2017 "Developing the European Data Economy" (Economy 2017) has been one of the new pillars of the extended European Digital Single Market strategy designed to keep up with emerging trends and challenges. It focuses on defining and implementing the framework conditions for a European Data Economy, ensuring a fair, open and secure digital environment. The main focus was on ensuring the effective and reliable cross-border flow of non-personal data, and access to and reuse of such data, as well as looking at the challenges to the safety and liabilities posed by the Internet of Things (IoT).

[1]For this analysis of the AI and Data sector we are using data from the Worldwide Semiannual Artificial Intelligence Systems Spending Guide 2018.

Large companies and SMEs in Europe see the real potential of big data value in causing disruptive change in markets and business models. Companies intending to build and rely on data-driven solutions appear to have begun to fruitfully address challenges that extend well beyond technology usage. The successful adoption of big data requires changes in business orientation and strategy, processes, procedures and organisational set-up. European enterprises are creating new knowledge and are starting to hire new experts, enhancing a new ecosystem.

In 2020 the EC renewed its Data strategy (*Communication: A European strategy for data* 2020) and identified Data as an essential resource for economic growth, competitiveness, innovation, job creation and societal progress. A critical driver for the emerging AI business opportunities is the significant growth of data volume and the rates at which data is generated. By 2025, there will be more than 175 zettabytes of data),[2] reflecting a fivefold growth of data from 2018 to 2025. At the same time, we see a shift of data to the Edge. In 2020, 80% of processing and analysis takes place within data centres, and the move is on to process more data at the Edge of the network in smart connected devices and machines. This creates new opportunities for Europe to lead this form of data processing and for European actors to maintain and control the processing of their data. As EU Commissioner Thierry Breton stated, "***My goal is to prepare ourselves so the data produced by Europeans will be used for Europeans, and with our European values***."

Data enables AI innovation, and AI makes data actionable. Data flows link together the emerging value chains disrupted by new AI services and tools, where new skills, business models and infrastructures are needed. The data governance models and issues such as data access, data sovereignty and data protection are an essential factor in the development of sustainable AI-driven value chains respecting all stakeholder interests, particularly SMEs, who are currently lagging in AI adoption.

AI innovation can generate value not only for business but also for society and individuals. There is increasing attention to AI's potential for social good, for example contributing to achieving the UN's sustainable development goals and the environmental goals of the EU Green Deal, and fighting against COVID-19 (Coronavirus disease) and other pandemics (Vaishya et al. 2020). Enterprises are developing sustainability programmes in the context of their CSR strategies, leveraging data and AI to reduce their environmental footprint, cutting costs and contributing to social welfare at the same time. Business and social value can be pursued at the same time, encouraging the reuse and sharing of data collected and processed for AI innovation (sharing private data for the public good, Business to Government (B2G) and not only Business to Business (B2B)). Expertise is needed to increase awareness about the potential value for society and people, as well as the business of data-driven innovation combined with AI, and to use this assessment to prioritise public funding.

[2]Vernon Turner, John F. Gantz, David Reinsel and Stephen Minton, *The digital universe of opportunities: rich data and the increasing value of the Internet of Things*, Report from IDC for EMC April 2014.

For the European Data Economy to develop further and meet expectations, large volumes of cross-sectoral, unbiased, high-quality and trustworthy data need to be made available. There are, however, important business, organisational and legal constraints that can hinder this scenario, such as the lack of motivation to share data due to ownership concerns, loss of control, lack of trust, the lack of foresight in not understanding the value of data or its sharing potential, the lack of data valuation standards in marketplaces, the legal blocks to the free flow of data and the uncertainty around data policies. The exploration of ethical, secure and trustworthy legal, regulatory and governance frameworks is needed. European values, e.g. democracy, privacy safeguards and equal opportunities, can become the trademark of European Data Economy technologies, products and practices. Rather than be seen as restrictive, legislation enforcing these values should be considered as a unique competitive advantage in the global data marketplace.

4 Developing a European Big Data Value Ecosystem

A Data Ecosystem is a socio-technical system enabling value to be extracted from data value chains supported by interacting organizations and individuals. Within an ecosystem, data value chains can be oriented to business and societal purposes. The ecosystem can create the conditions for a marketplace competition between participants or enable collaboration among diverse, interconnected participants that depend on each other for their mutual benefit. Data Ecosystems can be formed in different ways around an organisation or community technology platforms, or within or across sectors (Curry 2016).

Creating a European data ecosystem would "bring together data owners, data analytics companies, skilled data professionals, cloud service providers, companies from the user industries, venture capitalists, entrepreneurs, research institutes and universities" (DG Connect 2013). However, in the early 2010s, there was no coherent data ecosystem at the European level (DG Connect 2013), and Europe was lagging behind in the adoption of big data. To drive innovation and competitiveness, Europe needed to foster the development and broad adoption of data technologies, value-adding use cases and sustainable business models. There were significant challenges to overcome.

4.1 Challenges

To understand the difficulties that existed in establishing a European data ecosystem, it is useful to look at the multiple challenges (Cavanillas et al. 2016a) that needed to be overcome:

- *Low rates of big data adoption:* The European industry was lagging in the adoption of big data solutions. Many businesses and NGOs were uncertain of how to apply the technology within their operations, what the return on investment would be and how to deal with non-technical issues such as data privacy.
- *A disconnection between data owners and data innovators:* Many data owners (often large organisations) possessed large datasets, but they could not fully utilize big data's innovation potential. Data entrepreneurs and innovators (often SMEs and researchers) had vital insights on how to extract the value but lacked access to the data to prove their innovation. This mismatch created an impasse which needed to be overcome if innovation was to flourish.
- *Lack of technical and non-technical big data skills:* A key challenge for Europe was the provision of appropriately skilled people who had an excellent grasp of the best practices and technologies for delivering big data solutions. There was a shortage of data scientists and engineers who had expertise in analytics, statistics, machine learning, data mining and data management. Strong domain knowledge of how to apply big data know-how within organisations to create value was and still is a critical but rare skill.
- *Next-generation technologies:* US organizations had mainly driven the first generation of big data technology. It was essential to develop European leadership in the next generation of big data technology. Leadership in this space was critical for job creation and prosperity by creating a European-wide competency in technology and applications.

A thriving data ecosystem would need to overcome these challenges and bring together the ecosystem stakeholders to create new business opportunities, more access to knowledge and benefits for society. For Europe to seize this opportunity, action was needed.

4.2 A Call for Action

Big data offers tremendous untapped potential value for many sectors, however, there was no coherent data ecosystem in Europe. As Commissioner Kroes explained, "The fragmentation concerns sectors, languages, as well as differences in laws and policy practices between EU countries" (European Commission 2013; Neelie 2013). To develop its data ecosystem, Europe needed strong players along the big data value chain, in areas ranging from data generation and acquisition, through data processing and analysis, to curation, usage, service creation and provisioning. Each link in the value chain needed to be strong so that a vibrant big data value ecosystem could evolve.

The cross-fertilisation of a broad range of organisations (business, research and society) and data was seen as the critical enabler for advancing the data economy in Europe. Stakeholders from all along the Data Value Chain needed to be brought together to create a basis for cooperation to tackle the complex and multidisciplinary

challenges to create an optimal business environment for big data that would accelerate adoption within Europe. During the ICT 2013 Conference, Commissioner Kroes called for a European public-private partnership on big data to create a coherent European data ecosystem that stimulates research and innovation around data, as well as the uptake of cross-sector, cross-lingual and cross-border data services and products.

4.3 The Big Data Value PPP (BDV PPP)

Europe needed to aim high and mobilise stakeholders throughout society, industry, academia and research to enable the creation of a European big data value economy. It needed to support and boost agile business actors; deliver products, services and technology; and provide highly skilled data engineers, scientists and practitioners along the entire big data value chain. The goal was an innovation ecosystem in which value creation from big data flourishes.

To achieve these **goals the European contractual Public-Private Partnership on Big Data Value (BDV PPP)** was signed on 13 October 2014. This marked the commitment of the European Commission, industry and partners from academia to build a data-driven economy across Europe, mastering the generation of value from big data and creating a significant competitive advantage for European industry, thus boosting economic growth and jobs.

The BDV PPP commenced in 2015 and was operationalised with the launch of the Leadership in Enabling and Industrial Technologies (LEIT) work programme of Horizon 2020. The BDV PPP activities addressed the development of technology and applications, business model discovery, ecosystem validation, skills profiling, regulatory and IPR environments, and many social aspects.

With an initial indicative budget from the European Union of €534M for the period 2016–2020 and €201M allocated in total by the end of 2018, the BDV PPP has already mobilised €1570M in private investments since the launch of the PPP (€467M for 2018). Forty-two projects were running at the beginning of 2019 and the BDV PPP in only 2 years developed 132 innovations of exploitable value (106 delivered in 2018, 35% of which are significant innovations), including technologies, platforms, services, products, methods, systems, components and/or modules, frameworks/architectures, processes, tools/toolkits, spin-offs, datasets, ontologies, patents and knowledge. Ninety-three percent of the innovations delivered in 2018 had economic impact and 48% had societal impact. By 2020, the BDV PPP had projects covering a spectrum of data-driven innovations in sectors including advanced manufacturing, transport and logistics, health, and bioeconomy. These projects have advanced the state of the art in key enabling technologies for big data value and in non-technological areas such as providing solutions, platforms, tools, frameworks, best practices and invaluable general innovations, setting up firm foundations for a data-driven economy and future European competitiveness in data and AI.

The BDV PPP has supported the emergence of a comprehensive data innovation ecosystem for achieving and sustaining European leadership in big data and delivering the maximum economic and societal benefits to Europe – its businesses and citizens. In 2018 alone, the BDV PPP organised 323 events (including European Big Data Value Forum, BDV PPP Summit, seminars and conferences) outreaching over 630,000 participants, and taking into account mass media. The number of people outreached and engaged in dissemination activities has been estimated at 7.8 million by the Monitoring Report 2018 (*Big Data Value PPP Monitoring Report 2018* 2019). According to the European Data Market Study,[3] there has been a significant expansion of the European Data Economy in recent years:

- The *number of Data Companies* increased to 290,000 in 2019, compared to 283,300 in 2018.
- The *revenues of Data Companies* in the European Union reached €83.5B in 2019 compared to €77B in the previous year, with a growth rate of 8%.
- The *baseline for Data Professionals* in the European Union in 2013 was 5.77 million. The number of data professionals increased to a total of 7.6 million by 2019 in the EU28, corresponding to 1.836 million jobs created for data professionals since 2013.

4.4 Big Data Value Association

The Big Data Value Association (BDVA) is an industry-driven international non-profit organisation which has grown over the years to over 220 members all over Europe, with a well-balanced composition of large, small and medium-sized industries as well as research and user organisations. BDVA has over 25 working groups organised in Task Forces and subgroups, tackling all the technical and non-technical challenges of big data value.

BDVA served as a private counterpart to the European Commission to implement the Big Data Value PPP programme. BDVA and the Big Data Value PPP pursued a common shared vision of positioning Europe as the world leader in the creation of big data value. BDVA is also a private member of the EuroHPC Joint Undertaking and one of the leading promoters and driving forces of the AI, Data and Robotics Partnership planned for the next framework programme Multiannual Financial Framework (MFF) 2021–2027.

The mission of BDVA was "*to develop the Innovation Ecosystem that will enable the data-driven digital transformation in Europe delivering maximum economic and societal benefit, and, to achieve and to sustain Europe's leadership on Big Data Value creation and Artificial Intelligence*." BDVA enabled existing regional multi-partner cooperation, to collaborate at European level through the provision of tools and know-how to support the co-creation, development and experimentation of pan-European data-driven applications and services, and know-how exchange. To achieve its mission, in 2017 BDVA defined four strategic priorities (Zillner et al. 2017):

- **Develop Data Innovation Recommendations**: Providing guidelines and recommendations on data innovation to the industry, researchers, markets and policy-makers
- **Develop Ecosystem**: Developing and strengthening the European big data value ecosystem
- **Guiding Standards**: Driving big data standardisation and interoperability priorities and influencing standardisation bodies and industrial alliances
- **Know-How and Skills**: Improving the adoption of big data through the exchange of knowledge, skills and best practices

BDVA developed a joint Strategic Research & Innovation Agenda (SRIA) on Big Data Value (Zillner et al. 2017). It was initially fed by a collection of technical papers and roadmaps (Cavanillas et al. 2016a) and extended with a public consultation that included hundreds of additional stakeholders representing both the supply and the demand side. The BDV SRIA defined the overall goals, main technical and non-technical priorities, and a research and innovation roadmap for the BDV PPP. The SRIA set out the strategic importance of big data, described the Data Value Chain and the central role of Ecosystems, detailed a vision for big data value in Europe in 2020, analysed the associated strengths, weaknesses, opportunities and threats, and set out the objectives and goals to be accomplished by the BDV PPP within the European research and innovation landscape of Horizon 2020 and at national and regional level.

5 The Elements of Big Data Value

To foster, strengthen and support the development and wide adoption of big data value technologies within an increasingly complex landscape requires an interdisciplinary approach that addresses the multiple elements of big data value. This book captures the early discoveries of the big data value community as an initial set of *Elements of Big Data Value*. This book arranges these elements into a classification system which is inspired by the periodic table for classifying chemical elements by atomic mass. Within our periodic table we have four groupings (see Fig. 1) containing elements focusing on similar behaviours needed for big data value covering (1) ecosystem, (2) research and innovation, (3) business, policy and societal elements, and (4) emerging elements. As we learn more about how to leverage and derive more value from data, we expect the elements of big data value to be challenged and to evolve as new elements are discovered. Just as the originators of the periodic table left room for new elements, The Periodic Table of the Elements of Big Data Value is open to future contributions.

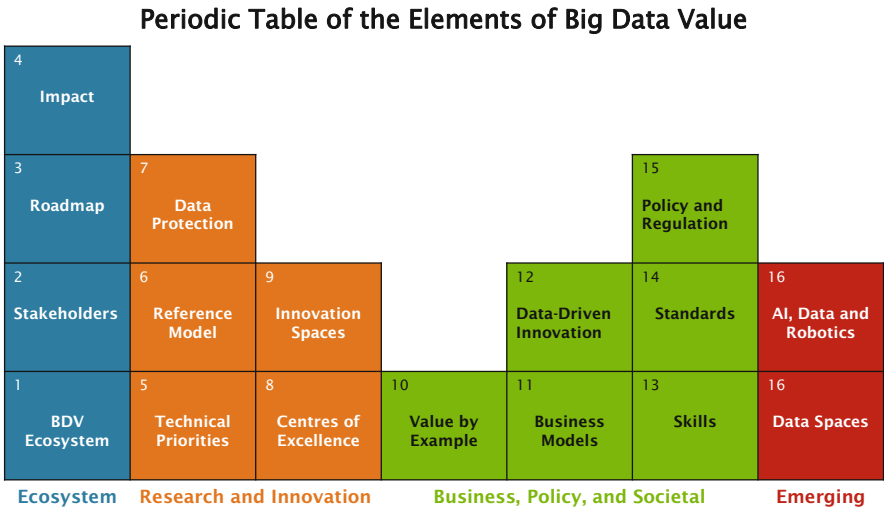

Fig. 1 The elements of big data value

5.1 Ecosystem Elements of Big Data Value

The establishment of the big data value ecosystem and promoting its accelerated adoption required a holistic approach to make it strong, vibrant and valuable to its stakeholders. The main elements that needed to be tackled to create and sustain a robust data ecosystem are as follows:

- **BDV Ecosystem:** This chapter explores the opportunity to increase the competitiveness of European industries through a data ecosystem by tackling the fundamental elements of big data value, including the ecosystem, research and innovation, business, policy and regulation, and the emerging elements of data-driven AI and common European data spaces.
- **Stakeholders:** Chapter "Stakeholder Analysis of Data Ecosystems" discusses a stakeholder analysis concerning data ecosystems and stakeholder relationships within and between different industrial and societal case studies. The stakeholder analysis helps determine how to incentivise stakeholders to participate in the activities of the data ecosystem. Each case study within the analysis focuses on big data practices across a range of industrial sectors to gain an understanding of the economic, legal, social, ethical and political externalities. A horizontal analysis is conducted to identify how positive externalities can be amplified and negative externalities diminished.
- **Roadmap:** A roadmap to drive adoption of data value ecosystems is described in Chap. "A Roadmap to Drive Adoption of Data Ecosystems". Creating a productive ecosystem for big data and driving accelerated adoption requires an interdisciplinary approach addressing a wide range of challenges from access to data and infrastructure, to technical barriers, skills, and policy and regulation. Overcoming

these challenges requires collective action from all stakeholders working together in an effective, holistic and coherent manner. To this end, the Big Data Value Public-Private Partnership was established to develop the European data ecosystem and enable data-driven digital transformation, delivering maximum economic and societal benefit.

- **Impact:** Chapter "Achievements and Impact of the Big Data Value Public-Private Partnership: The Story so Far" details the impact of the Big Data Value Public-Private Partnership, which plays a central role in the implementation of the European Data Economy. The chapter provides an overview of the partnership and its objectives, together with an in-depth analysis of the impact of the PPP.

5.2 Research and Innovation Elements of Big Data Value

New technical concepts will emerge for data collection, processing, storing, analysing, handling, visualisation and, most importantly, usage, and new data-driven innovations will be created using them. The key research and innovation elements of big data value are as follows:

- **Technical Priorities:** Chapter "Technical Research Priorities for Big Data" details the technical priorities for big data value covering key aspects such as real-time analytics, low latency and scalability in processing data, new and rich user interfaces, interacting with and linking data, information and content, all of which have to be developed to open up new opportunities and to sustain or develop competitive advantages. As well as having agreed approaches, the interoperability of datasets and data-driven solutions is essential to ensure broad adoption within and across sectors.
- **Reference Model:** Chapter "A Reference Model for Big Data Technologies" describes the Big Data Value Reference Model, which has been developed with input from technical experts and stakeholders along the whole big data value chain. The BDV Reference model serves as a common reference framework to locate data technologies on the overall IT stack. It addresses the main concerns and aspects to be considered for big data value systems.
- **Data Protection:** Data Protection and Data Technologies are the focus of Chap. "Data Protection in the Era of Artificial Intelligence: Trends, Existing Solutions and Recommendations for Privacy-Preserving Technologies", where advances in privacy-preserving technologies are aimed at building privacy-by-design from the start into the back-end and front-end of digital services. They make sure that data-related risks are mitigated both at design time and run time, and they ensure that data architectures are safe and secure. The chapter discusses recent trends in the development of tools and technologies that facilitate secure and trustworthy data analytics.
- **Centres of Excellence:** Chapter "A Best Practice Framework for Centres of Excellence in Big Data and Artificial Intelligence" presents a best practice

framework for Centres of Excellence for Big Data and AI. Within universities, academic departments and schools, it often works towards the establishment of a special-purpose organizational unit within a national system of research and education that provides leadership in research, innovation and training for Big Data and AI technologies. Centres of Excellence can serve as a common practice for the accumulation and creation of knowledge that addresses the scientific challenges of Big Data and AI, opens new avenues of innovation in collaboration with industry, engages in the policy debates, and informs the public about the externalities of technological advances.

- **Innovation Spaces:** Within the European data ecosystem, cross-organisational and cross-sectorial experimentation and innovation environments play a central role. Chapter "Data Innovation Spaces" describes the European Innovation Spaces, which are the main elements to ensure that research on big data value technologies and novel applications can be quickly tested, piloted and exploited to the maximum benefit of all the stakeholders.

5.3 Business, Policy and Societal Elements of Big Data Value

Big data is an economic and societal asset that has significant potential for the economy and society. New sustainable economic models within a policy environment that respects data owners and individuals are needed to the deliver value from big data. Critical elements of big data value for business and policy are as follows:

- **Value Creation:** Chapter "Big Data Value Creation by Example" provides a collection of stories showing concrete examples of the value created thanks to big data value technologies. These novel solutions have been developed and validated by stakeholders in the big data value ecosystems and provide proof points of how data can drive innovation across industries to transform business practices and society. Meanwhile, start-ups are working at the confluence of emerging data sources (e.g. IoT, DNA, high-definition images, satellite data) and new or revisited processing paradigms (e.g. Edge computing, blockchain, machine learning) to tackle new use cases and provide disruptive solutions.
- **Business Models:** Chapter "Business Models and Ecosystem for Big Data" explores new data-driven business models as ways to generate value for companies along the value chain, regardless of sector or domain: optimising and improving the core business; selling data services; and, perhaps most importantly, creating entirely new business models and business development. Identifying sustainable business models and ecosystems in and across sectors and platforms will be an important challenge. In particular, many SMEs that are now involved in highly specific or niche roles will need support to help them align and adapt to new value chain opportunities.

- **Data-Driven Innovation:** Chapter "Innovation in Times of Big Data and AI: Introducing the Data-Driven Innovation (DDI) Framework" introduces the Data-Driven Innovation (DDI) Framework to support the process of identifying and scoping big data value. The framework guides start-ups, entrepreneurs and established companies alike in scoping promising data business opportunities by analysing the dynamics of both supply and demand.
- **Skills:** Chapter "Recognition of Formal and Non-formal Training in Data Science" covers the data skills challenge to ensure the availability of appropriately skilled people who have an excellent grasp of the best practices and technologies for delivering big data value solutions. Promoting the "transparency and recognition of skills and qualifications" is particularly relevant to the task of recognizing both formal and informal data science training, and consequently the challenge will be to provide a framework in order to validate these skills.
- **Standards:** Chapter "The Road to Big Data Standardisation" covers the critical topic of standards within the area of big data where the use of standardised services and products is needed to effectively drive the adoption of common data solutions and services around the world. This chapter provides an overview of the key standardisation activities within the European Union and the current status and future trends of big data standardisation.
- **Policy and Regulation**: Chapter "The Role of Data Regulation in Shaping AI: An Overview of Challenges and Recommendations for SMEs" engages in the debate on data ownership and usage, data protection and privacy, security, liability, cybercrime and Intellectual Property Rights (IPR). A necessary first step is to frame this policy and regulatory debate about the non-technical aspects of big data value creation as part of the data-driven economy. These issues need to be resolved to remove the barriers to adoption. Favourable European regulatory environments are required to facilitate the development of a genuine pan-European big data market. For an accelerated adoption of big data, it is critical to increase awareness of the benefits and the value that big data offers, and to understand the obstacles to building solutions and putting them into practice.

5.4 Emerging Elements of Big Data Value

Artificial Intelligence (AI) has tremendous potential to benefit citizens, economy and society. From a big data value perspective, AI techniques can extract new value from data to enable data-driven systems that in turn enable machines and people with digital capabilities, such as perception, reasoning, learning and even autonomous decision-making. Data ecosystems are an essential driver for data-driven AI to exploit the continued growth of data. Developing both of these elements together is critical to maximising the future potential of big data value:

- **Artificial Intelligence, Data and Robotics:** To maximise the potential of AI, a solid foundation is needed for successfully deploying AI solutions. To this end, Chap. "Data Economy 2.0: From Big Data Value to AI Value and a European Data Space" details the *European AI, Data and Robotics Framework* (Zillner et al. 2020), which represents the legal and societal fabric that underpins the impact of AI on stakeholders and users of the products and services that businesses will provide. The *AI, Data and Robotics Innovation Ecosystem Enablers* represent essential ingredients for significant innovation and deployment to take place within this framework. Finally, *Cross Sectorial AI, Data and Robotics Technology Enablers* are needed to provide the core technical competencies that are essential for the development of data-driven AI systems.
- **Data Spaces:** As part of the continued development of the European Big Data Value Ecosystem, Chap. "Data Economy 2.0: From Big Data Value to AI Value and a European Data Space" describes common European data spaces which will be established to ensure that more data becomes available for use in the economy and society while keeping companies and individuals who generate data in control. These data spaces (in both a technical Curry 2020] and regulatory [European Commission 2018] sense) will be critical to fuelling data-driven AI innovations.

6 Summary

Exploiting big data offers enormous potential to create value for European society, citizens and businesses. Europe needs to embrace new technology, applications, use cases and business models within and across various sectors and domains. In this chapter, we presented the European strategy followed by the European big data value ecosystem to increase the competitiveness of European industries by addressing fundamental elements of big data value. These elements will enable data-driven digital transformation in Europe, delivering maximum economic and societal benefit, and achieving and sustaining Europe's leadership in the fields of big data value creation and Artificial Intelligence.

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