DATA AS ECONOMIC GOODS:
DEFINITIONS, PROPERTIES, CHALLENGES, ENABLING TECHNOLOGIES FOR FUTURE DATA MARKETS

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Abstract *– The notion that data has value is commonly recognised. However, data value is different from those associated with the consumable goods. There is a number of initiatives to create data markets and data exchange services. Existing business model of paid or commercial data(sets) services such as data archive are based on services subscription fee. However emerging data driven technologies and economy facilitate interest to making data a new economic value (data commoditisation) and consequently identification of the new properties of data as economic goods. The following properties are leveraging FAIR data properties and defined as STREAM properties for industrial and commoditised data: Sovereign, Trusted, Reusable, Exchangeable, Actionable, Measurable. Other properties to be considered and necessary for defining workable business and operational models: nonrival nature of data, data ownership, data quality, value, privacy, integrity, and provenance*. The paper refers to other discussions and projects on defining data as consumable goods and market mechanisms that can be applied to data exchange, such as Data Markets, Data Exchange, Industrial Data Space.

Keywords – Big Data, Big Data Infrastructure. Open Data, Data Markets, Data Exchange, STREAM Data properties, FAIR principles, Data Management

1. INTRODUCTION

The emergence of data driven economy, powered by Big Data and Cloud Computing technologies [1, 2, 3], motivates research and exploitation of data market and data exchange models that can facilitate/enable effective data exchange as economic goods and application specific integration while protecting personal data, data ownership and IPR.

Companies, government bodies, academic institutions and citizens have access to and are growingly using more data today than it could be imagined a decade ago. Traditional data sources such as company databases and applications are now complemented by variety of Open Data and Social Media data or sensors embedded in IoT devices, including mobile devices, smart meters, cars and industrial machines. Economy digitalisation and growing volume of data created an entirely new market of Big Data technologies and services to help organisations capture and extract value from all the data. The revenue from Big Data technologies and services, however, is small compared to the value that is expected to result in sectors such as trade, manufacturing, finance and insurance, public administration, and health and social care that now have the tools at their disposal to make innovative use of data to drive high-value business and societal outcomes [4]. Unleashing the full potential of data produced by digital economy will require both creation of infrastructure to facilitate data exchange and development of new market models and mechanisms.

The fact that data has value is commonly recognised. However, data value is different from those associated with the consumable goods. There is a number of initiatives to create data markets and data exchange services. Existing business model of paid or commercial data(sets) services such as data archives are based rather on service subscription fee than measurable properties of data. Quality of datasets is in many cases assessed by independent certification body or based on peer review by expert. Such model is useful for specific use cases but doesn't provide consistent model to make data an economic goods and enable data commoditisation (i.e. transforming data into object of trade and exchange [5]). Interest to make best use of research data resulted in formulation of the FAIR (Findable – Accessible – Interoperable – Reusable) data principles [6] which are fully accepted by the international research community and widely supported by industry and business. However emerging data driven technologies and economy facilitate interest to making data a new economic value (data commoditisation) and consequently identification of the new properties of data as economic goods. The paper leverages FAIR principles to define the proposed STREAM data properties for industrial and commoditised data: Sovereign, Trusted, Reusable, Exchangeable, Actionable, Measurable. Other data properties important to enable workable/actionable business and operational models include data ownership, data quality, data value, privacy, integrity, and auditability.

The paper refers to past and ongoing discussions to define data as economic goods and market mechanisms that can be applied to data, such as Data Markets, Data Exchange, Industrial Data Space.

The remainder of the paper is organised as follows. Section 2 analyses the emerging data driven economy and identifies data markets as important driving force. Section 3 discusses gaps and challenges on the adoption of Data Market. Section 4 introduces the proposed STREAM data properties and explain their importance in the context of data markets. Section 5 analyses the Data Market concepts and defines the main functional components and mechanisms required to enable Open Data Markets and Data Exchange. Finally, the conclusion section provides summary and invites for future discussion.

2. DATA ECONOMY AND DATA MARKETS

The European data economy is growing at a fast pace and will continue to do so in the upcoming years. The overall value of the data economy grew from €247 billion in 2013 to almost reaching €300 billion in 2016. According to the estimates of the European Data Market study, the value of the data economy in 2016 was worth nearly 2% of the European GDP. By 2020, the data economy is expected to increase to €430 billion with an overall impact of 2.5% on the GDP in the baseline scenario, which is defined by a continuation of the positive but moderate growth trend of the economy [7].

A data driven economy uses processes and products/services digitalisation, it collects and processes large amounts of data that include both personal and non-personal data. For personal data, the recently enacted GDPR mandates multiple measures to protect Personally Identifiable Data, in particular informed consent [8] what should build a further confidence and trust in digital technologies and build trusted environment for data exchange via the future data market [9]. In fact, research has shown that people tend to share more data when they trust the companies processing the data. Data economy tends to involve maximum possible amounts of data that may be produced by multiple sources, so creating a trusted environment for data exchange and trading is a key enabling factor for Data Markets and data driven technologies. Data quality and veracity are important properties of data for data driven applications.

2.1 Data Markets as Enabling Mechanism for Data Economy

The establishment of the Open Data Market as a necessary stage in making Digital Single Market (DSM) in Europe reality and working to facilitate the digital transformation of European economy to embrace new trend related to Industry 4.0 [10] and data driven technologies. Data Markets are recognised as a priority topic in the Horizon 2020 Work Programme 2018-2020 [11]. Currently data exchange is limited to Open Data (including social media data, city data, governmental data etc.) while customer activity data, personal data, business operational data and industrial data, that has a strong potential of bringing global optimisation to multiple human/social activities and resources use, still remain in proprietary/private custody by companies, what brings unfair benefits to big network(ed) and technology companies that all tend to create their own full set of data that they collect from their business and operational network. Data Markets [11] and Data Exchange [12] have a potential to bring benefit for facilitating business activity, social creativity and technology advancement, but current infrastructure, data protection, legal conditions and regulations are not ready to offer the necessary environment. There are multiple initiatives and projects that have collected valuable experiences, however most of them are of an ad-hoc nature and involved limited number of stakeholders, they are not based on sufficient conceptual research, which in its own turn would require significantly wider experience and observation basis.

2.2 Data Driven Economy and Technology Integration

As described in the recent studies and reports there are clear trends of all technologies digitalisation and increased demand of advanced/smart data handling to enable full potential of data driven technologies. This is characterised by wide technologies integration based on modern Big Data infrastructure and technologies which are predominantly cloud based.

Data processing and data analytics require continuous data storage and exchange between applications and processes, what needs to be supported by scalable distributed data storage infrastructure, such as using Hadoop Distributed File System (HDFS) [13], Data Lake Storage [14], and facilitated by a special functional component such as Data Exchange, which can be a part of the Data Market [12] in a general business scenario.

Currently there is no common approach and architecture model to address the potential cross industry, cross-applications and cross-platform integration and exchange of data and data driven applications. Most of current developments and use of data in data analytics and data-driven applications require and remain inside vertical data processing stacks (typically belonging to one company). Best examples of effective data use for business purposes and offering data analytics platforms for business as services are provided by Big Data infrastructure and cloud providers such as Amazon Web

Services (AWS), Microsoft Azure, Google Cloud Platform, IBM, Facebook. All these companies combine three key components of the modern hub/networked digital economy [15]: (1) (Big Data) computation and storage infrastructure together with business (data analytics) services, (2) direct business services and marketplace, (3) wide/extended customer base and/or access created around products or services. In recent research [16], this types of companies are defined as "superstars" that achieve their market dominance by using exclusiveness of information and data collection in data driven economy. Besides regulation measures suggested in [16], necessary data market and data exchange mechanisms need to be created to allow data exchange at all stages of the data value chain from data production to data analysis and business application.

There are few European projects that address general issues of data protection, policies, exchange. However, there is no common vision and widely accepted approach to create Open Data Markets that would benefit big and small companies. European Union (EU) and Member States, anticipating the DSM paradigm, invested significant resources in building advanced Digital Infrastructure and regulatory basis for digital economy in Europe. Recent development of digital and data services is primarily based on individual companies' genius that discover and explore unique business opportunities. However, despite bright examples like Facebook, Twitter, Instagram and other social network and social media platforms that actually demonstrated the potential of data driven and digital technologies, the full potential of the data driven economy is not realised yet. The recent years technology development is characterized by conceptual research lagging behind occasionally generated business opportunities.

Further development of data driven technologies must combine conceptual research and development and implementation of economy wide technological platforms for data collections, storage, exchange and integration with the industry, business and social applications.

3. CHALLENGES IN DATA MARKETS ADOPTION

Based on the analysis provided above, we can define the general gap that creates a number of challenges for future data economy development and data markets adoption: Data are becoming an economic goods but there is no facility to unleash their full market potential.

We can list some of the identified challenges that motivated current research by the authors while actively developing the modern data infrastructure for data driven research and industry:

- Data property as economic goods and commodity is not researched and not defined. Data is more than oil of the future economy.
- There is no common vision and model how to trade data while retain data ownership and sovereignty
- The new Data Market model needs to be developed and adopted
- GDPR provides common rules but there is no clear technology alignment to implement and enforce GDPR requirements. New ePrivacy legislation will make data management rules even stricter.
- There is no (or limited) coordination and interaction between industry and academia to develop new market mechanisms.

Technological aspects bring additional complexity to the topic of building Data Markets.

Use of modern Cloud Computing and Big Data technologies and infrastructure is inevitable but there is no well developed security and trust model for storing and processing sensitive/proprietary data on cloud.

4. DATA PROPERTIES AS ECONOMIC GOODS

This section provides suggestions about defining data properties as economic goods and explains their importance for enabling data markets and facilitates data exchange. The section refers to related works that created background in defining the proposed data properties.

4.1 From FAIR principles to STREAM properties

Initially proposed by the research community, the FAIR (Findable – Accessible – Interoperable – Reusable) data principles [6,19] found also strong support among industry and currently included as a priority topic in the Horizon 2020 EOSC (European Open Science Cloud) Programme [20]. The FAIR principles are complied with and extend the data governance and data management models at enterprises as defined in industry standards: the DAMA Data Management Body of Knowledge (DMBOK) [21] and CMMI Data Management Maturity model [22].

Factors that facilitate need for data trading as economic goods include but not limited to:

- IoT sensor network and farms that continuously produce data that potentially may be used by different organisations and produce secondary data that may have added value;
- Use of personal data for advanced market research and services development;

- Earth exploration data collected over years (such as from mining or oil/gas companies) that can be also offered on the market;
- Existing data archives which value may increase if data traded in more flexible and measurable way;
- Secondary data created from Open Data.

Emerging data driven technologies and economy facilitate interest to making data a new economic value (data commoditisation) and consequently identification of new properties of data as economic goods.

The following properties are leveraging FAIR data principles and defined as STREAM properties for industrial and commoditised data:

[S] Sovereign
[T] Trusted
[R] Reusable
[E] Exchangeable
[A] Actionable
[M] Measurable

Other data properties important to enable data commoditisation and allow data trading and exchange for goods include: Quality, Value, Auditability/Trackability, Branding, Authenticity, as well as original FAI(R)properties Findability, Accessibility, Interoperability. Special features that must be managed in all data transfer and transformation are data ownership and IPR. The data property originated from its digital form of existence defined as not-Rivalry, on one hand, makes data exchange (copying, distribution) easy, but on the other hand, creates problem when protecting proprietary, private or sensitive data or IPR.

Below we explain why these properties are important for effective data trading and exchange between data market participants along the whole data value creation flow/process.

a) Data Sovereignty

Data sovereignty allows companies, data owners to remain control over their data. It is important for business to enter the data market with their proprietary business data and be confident that their data are not compromised or used by third parties without consent from the data owner (or data controller). Sovereignty is a key principle of the Industrial Data Space Architecture as defined by International Data Space Association [18].

Often data sovereignty principle is opposed to a general data storage and processing on clouds where data reside in the cloud provider data centers and there is fear that companies may lose control over their data, or cloud provider may have unauthorised access to data or their use for business purpose. However, modern cloud and infrastructure virtualisation technologies, provider business models and compliance provide sufficient number of controls to satisfy security and trust requirements by companies to operate their businesses and host data on clouds (see CSA Complete Cloud Security Governance, Risk, and Compliance (GRC) Stack, Cloud Security Alliance [23]).

b) Trusted Data

Using data in decision making or in the processes control requires that data are trusted and verifiable. Trust in data is achieved by the whole process of data collection and by using verified models of the processes that data represent, which must be in general auditable. In most business cases, data trustworthiness is ensured by the reputation of the data provider but all aspects of data production and origin must be verifiable and auditable.

c) Data Reusability

Data reusability should allow multiple uses of data, even if not for original purposes data created. Normally, data represents events, entity or processes and are application agnostic. Data re-suability can create multiple opportunities for data economy actors, including Small and Medium Enterprises (SME) or individual researchers. Data re-usability should be supported by well defined metadata and well-documented data collection process. Data re-usability is part of the research data FAIR principles and is well supported by metadata management tools [19].

d) Data Exchangeability

Data exchangeability ensures that data can be exchanged between data producer and data consumer in general and be used for target applications or intended purposes. To much extent, this implies data formats and platforms and APIs compatibility, what is achieved by industry standardisation. In ideal, data exchange should be possible between compatible processes or applications during the whole data processing flow or data lifecycle. In the context of economic data value, exchangeability of data can also mean possibility of exchanging data for other economic goods or money. However, data pricing models are not addressed by the authors at this stage, although some references to related works are provided below.

e) Data Actionability

When data is purchased by companies they should serve the business purposes and contain necessary information to derived actionable decisions about operations or processes optimisations, in particular customer experience improvement or quality of services delivered. When data are used in industrial processes, the actionable data must be extracted and included into the industrial processes control. With increased use of Artificial Intelligence in industry, the spectrum and variety of data used in industrial production value chain is increasing and may included process monitoring data, logistics data, market data and user feedback data.

f) Data Measurability

Data measurability can be discussed at least in two aspects: as an important property for data valuation and exchange as economic goods, and a part of data handling on the data infrastructure platforms. The former still require additional research and effective data valuation models yet to be created. The latter is concerned with the resources that are required or consumed by the data storage or data processing facility or applications. This area is well developed and supported by modern cloud based data infrastructure. Both public cloud platforms (such as AWS or Microsoft Azure) and Open Source platform (such as OpenStack or CloudStack) provide rich opportunity to monitor cloud resources usage by all data handling processes with details up to processor cycles, storage transactions or network traffics volume. Such information is essential for infrastructure resources planning and costs estimation.

4.2 Combining Data and Algorithms

With the complexity of modern data collected and generated by human activity and IoT, there is a need to store/archive data with the corresponding Application Programming Interfaces (API) and containerised applications that can handle the stored data. Stored data must contain metadata and schema as well as the blueprint for use and deployment (ready for integration with the target applications). API management [22, 24] is important part of data management in modern data driven companies, that includes both accessing data from external providers/sources and providing own data to customers and application developers. "Algorithm economy" term was popular in 2016-2017 [25] as one of development direction of the emerging data driven economy but now API management is a necessary part of the modern enterprise data infrastructure.

4.3 Other related concepts and models

Defining data properties as economic goods is a new research area and requires complex approach involving different research and technology domains. There are not many published researches on this topic. The authors research is motivated by the need to consistently define requirements, architecture and services that must be provided by the Big Data infrastructure and such infrastructure components as Data Exchange and Data Markets.

Information and data value are admitted in many general publications and research related to Big Data value chain [26], emerging data driven hub economy [15] and macro-economic model of big technology firms (referred to in the paper as "superstar") [16]. However, these publications don't discuss data as economic goods that can be exchanged or traded for money.

Few papers and blog articles explored information as an asset. The seminal paper "Measuring the value of information: An asset valuation approach" by Daniel Moody and Peter Walsh (1999) [27] formulated 7 Laws of Information, which we quote here to facilitate further discussion and research (refer for details to the original paper [27]):

- First Law: Information is (infinitely) shareable
- Second Law: The value of information increases with use
- Third Law: Information is perishable
- Fourth Law: The value of information increases with accuracy
- Fifth Law: The value of information increases when combined with other information
- Sixth Law: More is not necessarily better
- Seventh Law: Information is not depletable

Two blog articles of 2013 [28] and 2014 [29] attempted to re-define the Moody&Walsh laws to Data Science [28] or apply them to information emerging from IoT and sensors [29].

Although the presented paper doesn't discuss data pricing and cost model, we mention two other papers by Muschalle, et al (2012) [30] and Heckman, et al [31] that discuss pricing approach for data markets. Their research can provide initial input for developing data pricing model and how it can be used in the data market operation.

5. DEFINING OPEN DATA MARKET

Data Markets is an important component of the Data economy that should unleash the full potential of data generated by digital economy and human activity in general. Future data markets should incorporate Open Data Market (ODM) model that should allow multiple market participants to join by complying to established rules and using standard APIs for data and information exchange. This section briefly discusses the ODM model and its functional components as a part of the modern data architecture and future data (driven) economy.

The proposed ODM approach leverages the International Data Space (IDS) architecture and functional model [17,18] that are strongly based on the concepts of data sovereignty and infrastructure federation to ensure architecture openness.

5.1 Modern Data Architecture

Modern data architecture is enabled by cloud and Big Data technologies and has the following characteristics:

- Capable to handle Big Data V-properties: Volume, Velocity, Variety, and addressing data Variability, Veracity, Value [1, 3]
- Cloud based, Elastic
- Customer-centric
- Automated, Smart
- Adaptable, powered by Agile and DevOps continuous improvement/deployment model [32]
- Combining data and algorithms (as part of containerised applications and data)
- Collaborative
- Governed
- Secure, Trusted

5.2 Characteristics of emerging data markets

Data markets should be able to support all major properties of Big Data from/for all application domains, allow data exchange and integration at different stages while preserving data provenance and auditability. Below is non-exhaustive list of Data Market properties leveraging Big Data architecture and powered by cloud technologies:

- Supporting heterogeneous data exchange at different processing stages
- Cloud powered/integrated
- Customer-centric
- Automated, Smart
- Regional/sectoral specialised
- Collaborative
- Governed
- Secure, Trusted
- Auditable
- Transparent
- Enabling data commoditisation and operating with monetised data values.

The listed above properties should provide a necessary framework for definition of the Open Data Markets architecture, at the same time they will require better definition of data as economic tradeable goods.

5.3 Data Market and Data Exchange functionality groups

The Data Markets and associated with them Data Exchanges include technological, trust management, legal, commercial and operational aspects, as described below.

5.3.1 Technical infrastructure

Infrastructure is a necessary component of any service architecture. The following are essential components of the Data Market infrastructure:

- Architecture and conceptual model of the Data Market space, including technological, organisational, legal and commercial aspects;
- Shared/Federated infrastructure to access and operate the Data Market;
- Federated hybrid cloud based Big Data infrastructure to support data storage, processing and exchange in a secure and trusted way;
- DataHubs support for generic services for data suppliers such as caching, streaming, containerised delivery;
- Support for on-demand connectivity and bandwidth provisioning between data handling services/hosts in the data lifecycle;
- Gateway based and computational enforcement of market policies and rules.

5.3.2 Rules for trust

Rules for trust provide basis for trusted relations between Data Market participants and reducing contractual and operational risk between participants. This includes the following rules, policies, services:

- Policy framework and platform bound mechanisms to participate in and cooperate with parties in the Data Market;
- Models for agreements between parties in the Data Market and end users, with engineering for scalable (software) contracts and supporting architecture;
- Compliance assessment tools of the Big Data Infrastructure to enable trusted interaction between market actors;
- Infrastructure and transactions auditing for performance and disputes.

5.3.3 Matching of parties (brokerage)

Brokerage and third party services are typical components of the traditional market exchange services, however it is not trivial to enable such services over Data Exchanges. The following are essential brokerage services to enable effective and trusted data exchange:

- Directory and registry services to enable findability of data and services, including data providers, target data applications and typical data uses, conditions, etc.;
- Data filtering and quality assessment services, data processing API, value added service/product offerings;

- Automated/assisted contracts negotiation and data "value/property" transfer/exchange, customer support.

5.3.4 Data Catalogues to keep all together

Data Catalogue (or Directory) is essential component of the intended Data Market and Data Exchange infrastructure that can be distributed and operate in centralised hierarchical and federate modes. Catalogue service should enable both hosting metadata information and historical/provenance information about data sets and data transformation. The following summarises the Data Catalogue properties and services:

- Cataloguing data sets
- Cataloguing data operations
- Metadata Catalogue
- Searching
- Data Curation
- Data Quality assessment and data categorisation
- Linking data properties and applications
- Recommendations and relationships
- Data sets evaluation
- Data access policies and API
- Usage metadata
- Lineage/Provenance
- Integration and interoperability
- Supporting data pricing models (current and future)
- Data visualisation (properties, usage, quality)
- Security
- Compliance

5.3.5 Data Exchange protocol

Data exchange protocols is an important component of the future Data Markets and Data Exchange infrastructure. Data exchange protocols can be provided as a part of the Data Exchange (as Data Market functional component) and use layered model benefiting from reliable and secure modern Internet protocols, while deploying specific data exchange protocols as upper layer protocols. Modern network and cloud virtualisation technologies allows building programmable virtualised networks that can be provided as part of Virtual Private Clouds (VPC) and support data applications that produce and consume data and involve data exchange internally inside secure VPC and with external parties.

Recent developments in data description and data management introduced a number of mechanisms that can be used for effective and consistent data exchange protocols and applications: Persistent data Identifiers (PID), Data Factories, Metadata and data types registry, data annotation and data discovery mechanisms – all these are part of the Research Data Alliance (RDA) outputs and recommendations [33].

CONCLUSION

The presented paper is intended to provide a basis for further wider discussion on defining data properties as economic goods and building future Open Data Market and Data Exchange infrastructure by involving concerned communities, in particular those that the authors are actively involved: Research Data Alliance, Industrial Data Space, European Open Science Cloud, and National Institute of Standards and Technologies (NIST) Big Data Working Group. The proposed definition of the STREAM data properties is based on extensive study of related works and authors' experience in building modern Big Data Infrastructure and cloud based services.

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