Big Data Monetization: Discoveries from a Systematic Literature Review

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Abstract— **This study investigated how monetization of data in a Big Data environment has been suggested in academic literature. Our goal was to find out what methods have been applied to determine the relevance and value of data in these environments and if these methods are based, in any way, on information theory. In order to come to a conclusion, we applied a formal process of systematic literature review based on the methodology suggested by Kitchenham. The results showed that, in spite of the progress made on the topics of Big Data and the application of analytical methodologies over the last decades, there is no method based on data that is widely used to determine the value of a datum in a Big Data environment. By observing the results, it is possible to conclude that little attention has been given to the dimension Value in academic studies related to Big Data when compared to searches directed to the other three classical dimensions (Volume, Velocity and Variety). More specifically, in terms of economic value, studies are even scarcer, and the existing ones do not share a common view on how to measure this value. If, on the one hand, monetization in Big Data environments is still a field that needs to be better explored in academic literature, on the other hand, these intangible assets, i.e., data, grow exponentially and are more and more present in the corporate world. It highlights the opportunity to develop studies in search of standards that can be widely accepted and used to this end.**

Keywords-Big Data; Big Data Monetization; Analytical Techniques; Artificial Intelligence; Systematic Literature Reviews; Digital Assets.

I. INTRODUCTION

In 1999, Mood and Walsh were the first to propose an economic view directed to digital assets. In their view, data represented the raw material, information systems (hardware & software) would be the manufacturers and information would be the finished product that would need to be priced [1].

In this study, we sought to understand how monetization in Big Data environments has been suggested in academic literature. Originally defined by Gartner in 2001 as "high-VARIETY data that are received at high VOLUME and at increasingly higher VELOCITY" [2]. This definition came to be known as the 3 Vs of Big Data. After this definition, many others have proposed new Vs to be added to the original definition [3]. At least two new Vs have been accepted as part of this definition: namely Veracity and Value [4]. The concept of each of these dimensions is detailed below [5]:

- Volume is the magnitude of large-scale datasets. The variation in the size of large-scale data relies on the structure and time of data, i.e., volume is the size of distinct types of data acquired from distinct data sources;
- Velocity is the rate at which the data is received and then refined for analytical purposes;
- Variety is a distinct type of data representation such as structured, semi-structured, and unstructured data;
- Veracity refers to the biases, noise, and abnormality in data. Veracity issues arise due to the process uncertainty (randomness in process), data uncertainty (data input uncertainty), and model uncertainty (approximate model);
- Value is another dimension of big data in the business perspective. Business organizations need to notice the value of big data, to increase the profit by minimizing the operational costs to provide better services to the customers;

We will focus our searches on the dimension Value, more specifically on the financial value that can be extracted from a certain datum in a Big Data environment.

For reaching our goal, we sought to find out which methods have been suggested or applied so as to determine the relevance and the value of data in Big Data environments. Additionally, if these methods are based on any kind of information theory, a mathematical theory, originally proposed by Shannon in 1948 [6], studies the quantification, storage and communication of information and ways in which it is applied in different areas.

In order to conduct this research, we applied a formal process of systematic literature review based on the methodology suggested by Kitchenham et al. [7]. This process was set in motion by the definition of the problem we want to solve and by the definition of the research questions, search protocols, selection, extraction and syntheses of the primary studies related to the theme. The process went on with the execution of previously defined protocols in the search for answers.

The results showed that, despite the progress in the theme of Big Data and improvements in the application of analytical methodologies over the last decades, there is not yet a method based on data that can be widely used to determine the value of a certain datum in a Big Data environment. According to the results we found, it is possible to conclude that academic research has given very little attention to the dimension Value, especially when compared to the research done on the other three classical dimensions (Volume, Velocity and Variety) [2]. More specifically, when it comes to financial value, research is

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even scarcer and the existing papers do not share a common view on the most suitable way to measure it.

If on the one hand, monetization of data in a Big Data environment is still a poorly explored field in academic literature, on the other hand, these intangible assets, the data, grow exponentially and are more and more present in the corporate world. This fact highlights the opportunity to develop studies in search of standards that can be widely accepted and used to this end.

This article is structured as follows: in Section 2, we explore the context that we have adopted in our study related to the topic of Big Data; in Section 3, we provide details on the protocols applied to the review; in Section 4, we present the results; in Section 5, we present the conclusion and suggest further future studies.

II. THEORETICAL FRAMEWORK

After analyzing studies from different sectors and applications with non-specified contexts, theories and designs, we use this section to contextualize both the population and the intervention related to this study.

A. Big Data

In spite of having given a definition to the origin of the term Big Data in the introduction, it is a fact that since its advent it has been used in a number of academic studies and commercial applications without a clear uniform meaning or context.

In a 2016 review comprising over a thousand and five hundred studies that mentioned the term "Big Data", De Mauro et al. [8] proposed the following definition that would be able to bundle most of the assessed texts: "Big Data is the information asset characterized by such a High Volume, Velocity and Variety to require specific Technology and Analytical Methods for its transformation into Value". This definition is the one taken into consideration in our study and what makes the theme of our review even more relevant, once it highlights that the explicit objective of a Big Data environment is to turn digital assets into value.

In our case, we searched for studies that proposed ways in which financial value can be extracted from data in the context herein.

B. The Value of Data as Digital Asset

"Many argue that Facebook did not "purchase" user registrations, but user data and user-generated data are the company's core asset, which led to the largest technology Initial Public Offering (IPO) in history" [1].

The debate on how "value" itself was formed has been going on for millennia, since pre-Christian era, when Aristotle argued that value is based on the need for exchange (Aristotle, 350 BC). This concept is in the core of economic adjustment and is the basis to define what will be produced, how it will be produced and who will produce it.

Another key discussion in economic theory includes questioning the reasons for a product or service to be priced the way it is, that is, how the value of a product or service is determined and how to calculate it correctly.

The theory was formulated and applied in a world where products and services were in their entirety represented by physical assets with well-defined characteristics: raw material, finished products and services provided by physical living beings (humans and animals).

The advent of computers brought the world a new category of assets, digital ones, represented in a discrete numerical way and used in digital devices with computational processing. These digital assets are capable of delivering a new category of products and services: better decisions, increased performance, competitive advantages and they can even be sold directly as a product. It is in this context of "data" as a digital asset and as a product itself that we will study the ways of monetization that have been proposed.

III. METHODS

The formal process of systematic literature review applied in this study was based on the methodology suggested by Kitchenham et al. [7]. Six steps composed our methodology: (1) development of the protocol, (2) identification of the criteria for inclusion and exclusion, (3) search for relevant studies, (4) data extraction, and (5) synthesis.

This review focuses on identifying primary studies that approached techniques that proposed ways for monetizing new data in a Big Data environment. Bearing this goal in mind, the next step was the definition of the problem that would guide the search for primary studies.

According to Eron Kelly, "In the next five years, we'll generate more data as humankind than we generated in the previous 5,000 years" [9]. In this setting, we have defined the problem:

- *How can we monetize new data generated and available in the Market in a Big Data environment?*

Our research questions are presented below. The aim is to discover methods either in use or suggested to determine both relevance and value of the datum in Big Data environments and to observe if any of them considers the information theory in their formation.

A. Research Questions

RQ1. What methods have been suggested or applied to determine the relevance of the datum?

RQ2. What methodologies have been applied to identify the value of a datum?

RQ3. Does the methodology to identify the value use the information theory in its formulation? How?

With the questions well defined, in the following sections we move on to defining the protocols for search, selection, extractions and detailed synthesis.

B. Search Protocol

We chose to perform an automatic selection that would guarantee the feedback of the highest possible number of articles that could answer our research questions. For such, we started by defining the search string. Table I below shows the search string we applied.

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TABLE I. SEARCH STRING

	Applied Search String	
	Search Terms	***Rational***
Population	("Big Data")	Studies that approach themes related to Big Data
	AND	
Intervention	"data assets" OR "value evaluation" OR "data monetization" OR "data marketplace" OR "information value" OR "data value" OR "business value"	Studies that must be related to monetization of data, that is, the extraction of financial value.

We have selected three (3) academic bases that congregate relevant studies in the context of software engineering and Big Data:

- ACM Digital Library;
- IEEE Xplore;
- ScienceDirect – Elsevier;

In the process of extracting information from the selected bases, the search strings were applied separately in each of them. The searches were conducted between May and June, 2020. The studies were grouped and then examined in search of duplicity. Table II shows the number of studies found in each selected base.

TABLE II. PAPERS SELECT BY DATABASE

Database	Amount of studies
ACM Digital Library	403
IEEE Xplore	162
ScienceDirect – Elsevier	1634

Figure 1 presents the number of studies returned in the search according to the year of publication. It is important to point out that in spite of being a recent theme, as the first studies date from 2012, it has gained increased attention by the year.

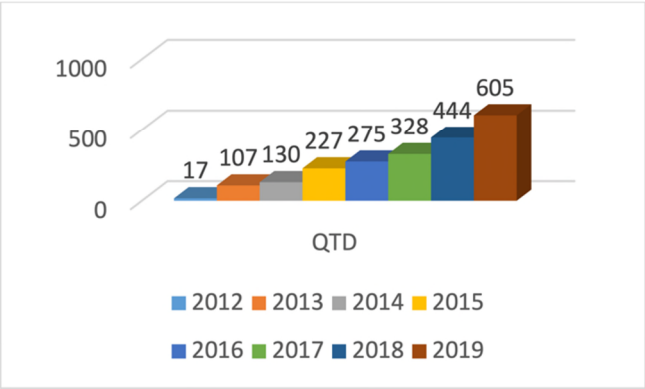

Figure 1. Studies grouped by year of publication.

We have observed a compound annual growth rate of 67% in the number of studies between 2012 and 2019. This shows how this theme has become more and more relevant and coherent with the increase in solutions and demands based on data.

C. Criteria for Inclusion and Exclusion

With well-defined string and bases, we focused our selection of articles in the period between 2012 and 2019. The starting point was 2012 for being the year where the first articles related to the theme were published. 2019 was chosen so as to guarantee the replicability of this study in future research (2020 is still ongoing and new articles might still arise for this period in future studies).

On the Criteria for Inclusion and Exclusion, we considered primary studies that would analyze ways of monetizing data, regardless of the context, sector or application.

Criteria for Inclusion: Besides the period of publication, we still defined as criteria for inclusion:

- Primary studies published in English;
- Studies that approach the theme of Big Data and monetization of data;
- Studies that answer at least one of the research questions.

Criteria for Exclusion:

- Academic or teaching-oriented articles;
- Short articles, courses, tutorials and secondary and tertiary studies (reviews);
- Duplicated studies (in these cases, only one version was considered).

D. Steps of the Selection

This section describes the selection process from the start by using the strategies described below in order to identify primary studies.

The first step was to obtain studies returned from the search in the databases by using the Zotero [10] and Ryyan platforms [11], both designed for managing publications and supporting reviews. We used these tools to conduct the steps listed below and in Figure 2 in the Results section, showing the number of articles that were filtered through each step until the final selection:

1. Elimination of duplicates and articles written in another language;
2. Search for keywords related to the theme;
3. Reading of the title;
4. Reading of the abstract;
5. Reading of the Introduction and Conclusion, and;
6. Reading of the full article.

In steps 2-6 above, many articles were eliminated for not mentioning ways of monetizing data in the Big Data context either in the title, abstract or keywords, others were also eliminated from the reading of the introduction and conclusion for clearly not approaching the research questions. Finally, in the Reading of the full article step, an additional number of studies were eliminated because, in spite of approaching themes related to the subject of this study, they did not present answers to the research questions.

Figure 2 shows the outcome of the execution of this protocol in the Results section.

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E. Extraction and Synthesis Protocol

We used a support form, from the Google Forms tool, to extract the evidence that answered the research question. This evidence was catalogued in a spreadsheet so it could be used in the following synthesis step.

A thematic synthesis was defined to our review, once the contexts, theories and designs of the selected articles do not follow specific standards. This method of synthesis is specially adjusted to these cases, once it allows to identify (codify) and report patterns (themes) based on the data extracted from primary qualitative studies [12].

IV. RESULTS

A. Conducting Search and Selection

The search was performed according to the protocol defined in the previous step and the results are presented in Figure 2.

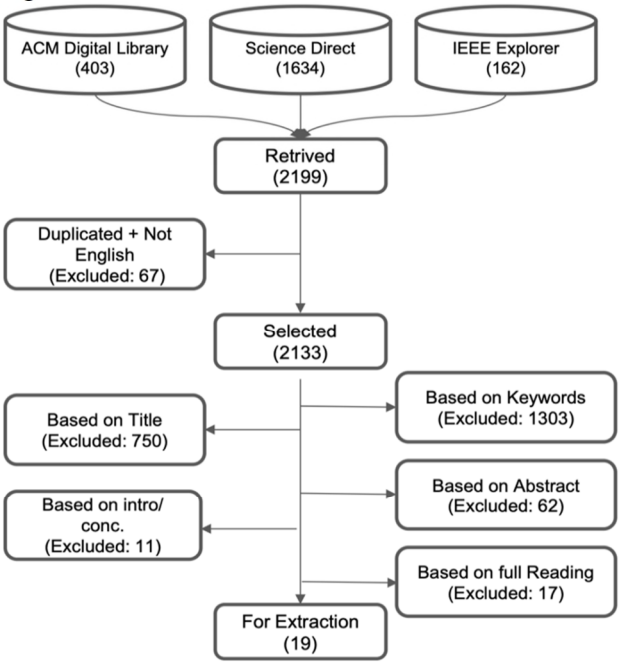

Figure 2. Results of the search and selection process.

A total of 2199 related studies were found in our search string for the defined period and, after the application of the inclusion and exclusion criteria and the steps for selection defined in our protocol, we were left with 19 primary studies to be dealt with in the following extraction and synthesis stages.

Table III presents the number of studies retrieved from each database. It is curious to observe that most of the studies where we found answers to our research questions came from the base that returned the fewest articles in our initial search. In general, at the end of the selection process, only a few studies approached our problem when compared to the original total of results at the beginning. Answers were found in less than 1% of the studies returned from the initial search.

TABLE III. STUDIES ANSWERING RESEARCH QUESTIONS BY DATABASE

Database	Studies for Extraction
ACM Digital Library	2
IEEE Xplore	12
ScienceDirect – Elsevier	5

B. Conduction the Extraction and Synthesis processes

We move on with the conduction of our protocol, now to the extraction and synthesis steps.

Each of the excerpts extracted from the 19 selected articles was codified for a future more detailed synthesis of the theme, according to the thematic synthesis methodology suggested by Cruzes and Dyba [12]. It starts with the identification of keywords in the extracted texts, followed by a process of codification of these texts into higher concepts and, at last, a definition of themes, grouping one or more of the generated codes. In Figure 3, we present the process we applied.

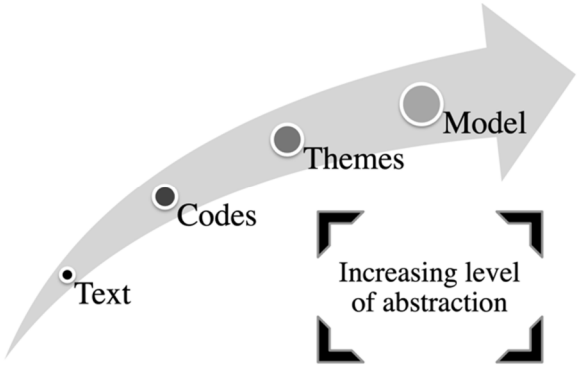

Figure 3. Process of synthesis applied to this study [12].

Table IV presents the answers found in each of the selected articles for each of the research questions.

TABLE IV. QUESTIONS ANSWERED BY ARTICLE

Study	RQ1	RQ2	RQ3	Total
[13]		1		1
[14]	1	1		2
[15]	2	1		3
[16]	1			1
[17]	1			1
[18]		1	1	2
[19]	1	1		2
[20]	1	1		2
[21]	1			1
[22]	1			1
[23]		1		1
[24]	1	1		2
[25]	1			1
[26]		1	1	2
[27]	1	1	1	3
[28]		1		1
[29]	1	1		2
[30]		1	1	2
[1]	1	1		2
Total	**14**	**14**	**4**	**32**

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We have found eight studies with answers to one of our questions and in ten other papers we found answers to two of our questions. Only one of the papers was able to answer our three research questions.

C. Answers to the Research Questions

This section approaches a detailed discussion on the results of the systematic review. The subsections provide answers to RQ1 - RQ3 research questions.

After the analysis and extraction steps have been done in primary studies, we were able to identify some aspects related to monetization of data in a Big Data environment based on these studies. The first conclusion is that the theme of monetization of data in a Big Data context is still a recent theme, as two thirds of the answers were found in studies published in the last 3 years. The second conclusion is that few theories and models were developed aiming to approach the theme of this research, once we were left with only 19 studies that were able to answer the research questions. Finally, among the few papers that proposed theories and models to meet the theme of this research, we have not been able to find a model or method that could be considered a standard.

It was surprising to find out that in order to valuate a datum in a Big Data context, techniques based on data are not the most commonly applied. This may sound like a contradiction at first, but it can also be interpreted according to the market law (supply x demand) even in these contexts.

Another hypothesis to justify this observation would be the natural stillness of concepts (inertia), usually applied to physical assets, with characteristics of scarcity, in an approach that would seem more natural in the context of digital assets (using data-based techniques in order to price data).

In this section, we summarize the answers to each of the research questions.

1) RQ1: What methods have been suggested or applied to determine the relevance of the datum?(14 answers)

a) In this review, the most applied methods to determine the relevance of data were the analytical techniques (50% of the findings, 7 cases);

b) Methods that evaluated the relevance of data in a business context were found in 29% of the cases (4 cases);

c) In 2 of the cases (14%) there were methods based in intrinsic characteristics on the data (kinds of data, volume, velocity, etc.);

d) Finally, in 1 of the articles, the use of the datum was applied as a method to determine the relevance of the datum (defined as the number of hits or references to a certain piece of information).

Even among the most used methods, it was not possible to find uniformity, for instance, in the case of the use of analytical techniques to determine the relevance of a datum, where many distinct techniques were applied without the predominance of a specific one.

2) RQ2: What methodologies have been applied to identify the value of a datum? (14 answers)

Table V summarizes the answers to this research question.

TABLE V. BASE FOR VALUE IDENTIFICATION

Way of determining value	%
SUPPLY X DEMAND	35.71%
ANALYTICAL TECHNIQUES	21.43%
USE OF THE DATUM (USE/HITS)	14.29%
BOOK VALUE	14.29%
RISK X RETURN	7.14%
INFORMATION THEORY	7.14%

In a simplified way, we have found that the supply x demand market law was the most common reference to determine the value of new data in a Big Data context, followed by analytical techniques (also highlighted in the previous question). Next in line, there were the methods based on the use of data, book value and, finally, a case was based on the price of risk x return and the other based on information theory.

3) Does the methodology to identify the value use the information theory in its formulation? How?

Although in only one of the cases the Information Theory has been used as a method to determine the value of new data, four other studies have referenced this theory in their considerations. Two studies cite entropy as a factor that is directly linked to pricing new data and two others refer to the exchange of information as a trigger to generate value, that is, no exchange, no value.

Many of the studies that proposed methods for valuating a datum considered that, despite the proliferation of the theme of Big Data, research to determine value in this context is still recent in academic literature.

V. CONCLUSIONS AND FUTURE WORK

As we finished the proposed systematic literature review process, in search for answers on how to monetize data in a Big Data context, the first conclusion was that the theme of monetization of data in this context is still recent in academic literature. The first studies that answered our questions in the researched bases dated from 2013 (2 studies) and 75% of the answers we found dated from 2017 on. Another conclusion is that very few theories and models were developed with the specific aim of approaching this theme, since out of 2199 studies in our initial search we ended up with only 19 that were able to address our research questions. In sum, it was possible to observe that less than one percent of the studies answered at least one of our questions. Finally, even among the few papers that proposed theories and models to answer the research questions, we could not find a pattern or method that would be considered a standard or even a most applied one.

The results showed that, despite the progress in the theme of Big Data and in the application of analytical methodologies over the last decades, there is not yet widely

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used data-based method to determine the value of a datum as a digital asset. Based on the studies we found, it is possible to conclude that very little attention has been given to the dimension Value in academic research when compared to the three classical dimensions (Volume, Velocity and Variety) of the original definition of Big Data. Research is even more scarce in terms of financial value, and the existing studies do not share a common view on the right way of measuring and defining this value.

The most surprising finding was the fact that, in order to valuate a datum in the context of Big Data, techniques based on data are not the most commonly applied. This may sound like a contradiction at first, but it can also be interpreted by the market law (supply x demand) even in contexts or by the natural stillness necessary to a change of approach that seems to be inevitable when considering the characteristics of digital assets.

If on the one hand monetization of data in Big Data environments is a poorly explored field in academic literature, these intangible assets grow exponentially and they are more and more present in the corporate world, which highlights the opportunity to develop research to find standards that can be widely accepted and used to this end. With future studies, we will delve deeper in the theme in search of models and standards for pricing data-based digital assets (analytical techniques).

We can consider as threats to the validity of this research the fact that we have not done manual search for articles and did not include commercial white papers in the scope. The main reason is that it was a first approach to the problem and our intention was to review the theme in academic literature in an automatic manner. Future works will also consider these additional steps.

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