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Employing Big Data & Analytics in Decision-Making: Factors Affecting Managers' Trustworthiness

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Abstract: The growing attention that Big Data & Analytics (BD&A) are actually raising among academics and practitioners is probably triggered by their almost infinite information potential. On the other side, BD&A hold specific peculiarities (source, structure of data or computational complexity), which may condition the inclination of users to consider them reliable.

This paper investigates the factors that may hinder or enable managers' trustworthiness about BD&A when used in support of planning and control, both at strategic and operational level where a different organizational learning is assumed to be required.

Using data from a survey, we find that the organizational learning mode significantly conditions the perceived usefulness of BD&A.

Additionally, managers' individual characteristics, under some conditions, may hinder their inclination to rely on BD&A. The findings contribute to literature on management accounting systems and on organizational learning and provide as well interesting managerial implications.

Keywords: Big Data & Analytics; Decision-Making; Data quality; Organizational Learning; Managers' perceptions.

1. Introduction

The usefulness of information in decision-making is a topic of "timeless concern" which becomes particularly crucial when a great amount of data is available for analysis (Moffitt et al, 2016).

Our challenge within this field of research is to investigate the factors impacting on the usefulness, as perceived by managers, and their consequent inclination to adopt Big Data & Analytics (BD&A) in support of decision-making.

BD&A have recently captured the attention of both scholars and practitioners. In the last 5 years, the literature has been definitely abundant in particular for what concern the development of complex processing techniques (Gandomi and Haider, 2015; Khan et al, 2017 only to name a few), while companies are strongly demanding for managers holding deep analytical skills and able to adopt BD&A techniques (Manyika et al, 2011).

However, lights and shadows emerge when BD&A are used in practice and, in several cases, this innovative information tools seem not to represent a good investment since managers may not be willing to rely on such a kind of information (Kwon, Lee and Shin, 2014). Managers' reluctance in adopting BD&A remains a quite unexplored issue in literature, which may be conditioned by several factors, that our paper aims to shed lights on. Particularly, we assume that intrinsic characteristics of BD&A, as well as organizational level in which decisions are taken and individual characteristics may play a significant role.

Using a survey of 117 managers and postgraduate students attending an MBA program, we find that the BD&A are perceived more useful when they are adopted at strategic level, rather than at operational level. For what concern the individual characteristics, we find that the level of experience and, surprisingly, the "confidence with numbers" (i.e. the managers practice supporting decision-making with information) act both as hindering factors on the perceptions of usefulness abut BD&A.

The results contribute to literature on management information systems in several directions. As first the paper extends current studies on data quality and usefulness of management information systems, to the peculiar context of BD&A. Likewise, our results contribute to literature on organizational learning and show that a higher perceived usefulness of BD&A is associated to decision processes which require exploration learning, which are common at strategic level. Finally, the results are also interesting under a managerial perspective, and particularly provide indications about the implementation and use of BD&A in a way to maximize the likelihood to be accepted and used by managers.

The paper is structured as follows: the theoretical framework and the development of the research questions are described in section 2, in section 3 the data and the methodology are described, in section 4 the results are discussed. Final considerations, limitations and future avenues for research conclude the paper.

2. Theoretical framework and research questions

As general purpose, a management information system should provide information which facilitates managerial decision-making and improve users' job performance. Today, to be successful, business have to take advantage of information technology, which represents the major force in conditioning the modern business world (Yeh and Teng, 2012). Reasonably, such a purpose is missed when managers do not perceive as useful to rely on the information available in support of decision-making.

Following a subjective research perspective, scholars generally aim to investigate consumers' perceptions and other factors, which may influence information systems adoption (Kwon, Lee and Shin, 2014). Within this last strand of research, our work aims to explore to what extent managers are inclined to use BD&A information in support of decision-making and which factors may significantly affect this inclination.

According to literature, perceived usefulness and ease of use are the most significant factors in influencing the managers' acceptance and consequently their inclination to adopt a given information technology (Yeh and Teng, 2012). The perceived usefulness has been described as the most powerful predictor for intention to use an information system both before its implementation (Venkatesh et al, 2003) and after its initial adoption (Bhattacherjee, 2001). This predictor, among others, is strongly influenced by the perceived data quality (DQ), which also represents a broad and multifaceted concept deeply investigated in literature.

In our paper we define DQ following the definition and the hierarchical framework of Wang and Strong (1996), which includes four dimensions (intrinsic, contextual, representational and accessibility), and is still considered by several more recent contributions (Hazen et al, 2014; Zaveri et al, 2016; Zheng, Zhao and Stylianou, 2013).
In our work, we particularly rely on intrinsic and contextual DQ, since the topic of BD&A can be investigated under either a technical or a subjective research perspective (Chen, Mao and Liu, 2014). Intrinsic DQ, depends on accuracy and objectivity which may generally be considered as drivers of DQ, but also on believability and reputation. Contextual DQ implies that the users' perceptions are influenced by the context in which information is used.

Basing on extant literature, in the following section we formulate hypotheses about a set of determinants assumed to impact on managers perceived usefulness about BD&A, which are summarized in the following categories: 1) BD&A intrinsic characteristics; 2) operating context; 3) managers' individual characteristics.

2.1 Intrinsic characteristics of BD&A information

In literature, intrinsic characteristics are widely considered a relevant driver of DQ (see Lee et al, 2002 for an extensive overview of literature). Intrinsic quality is generally investigated by considering four determinants, which are objectively measurable: accuracy, timeliness, consistency and completeness (Hazen et al, 2014). Accuracy and timeliness consider the extent to which data represent real phenomena and are up-to-date respectively. Consistency refers to the structural homogeneity of data, while completeness is the extent to which data are complete and free of errors.

Following an intuitive and a theoretical approach for selecting the data quality attributes (Wang and Strong, 1996), BD&A hold peculiar intrinsic characteristics which may influence the inclination of users to adopt them in support of decision making. BD&A are often described through the well-known 4Vs (Huge Volume, High Velocity, Huge Variety, and Uncertain Veracity), as well as by complex processing techniques (Cao, Chychyla and Stewart, 2015; Goes, 2014; IBM, 2012).

Huge volumes of data and complex algorithms may let these information tools be perceived as a black box, since the user is not allowed to assess the correctness of the information, or to understand the rationales lying behind the manipulation process. Additionally, BD&A often derive from external data-sources, which may condition particularly completeness and consistency, as well as the remaining intrinsic attributes. For these reasons data quality and validation of results may be concern of interest in a wide variety of applications (Kambatla et al, 2014).

Finally, the huge volumes of data impose archiving and processing problems to be solved both when external or internal sources are used (Vasarhelyi, Kogan and Tuttle, 2015).

In our study we intend to investigate whether and how managers involved in decision making perceive BD&A as more or less useful compared to alternative types of information which are different in terms of intrinsic characteristics.

Accordingly, we develop the following first research question:

RQ1: Different usefulness perceptions are associated to categories of information holding different intrinsic characteristics.

All the types of information considered in our study have been identified by following an empirical approach. In particular, 4 managers have been interviewed as described in section 3. The information items included in the analysis and their intrinsic characteristics are summarized in table 1.

Table 1: Information categories

Typology of information	accuracy	timeliness	consistency	completeness
Traditional management accounting information (TRAD)			high	high
Big Data & Analytics (BD&A)	high			
Experience accumulated over the years and information obtained through personal relations and interactions with customers and sales intermediaries (INFORMAL)		high		

Although in our study we do not intend to measure in detail the intrinsic attributes associated to the typologies of information considered in table 1, reasonably, the abovementioned categories are expected to hold different characteristics and this in turn could produce differences on users' perceptions. In particular, traditional management accounting information, may be easily perceived as complete and consistent, even if in some cases they might be not as accurate as needed. Similarly, managers may feel more confident in taking decisions by relying on their experiences and beliefs (Bertels, Koen and Elsum, 2015). Consequently, in some cases the usefulness of BD&A might compete with informal information, while in some other cases BD&A might overwhelm the informative power of traditional management accounting information.

2.2 Operating context
Drawing on organizational learning theory, we assume that the operating context may affect perceived data quality. In particular, managers may hold different perceptions about the same information when it is employed in support of decisions which entail a different way of reasoning.

In literature, exploration and exploitation are widely used to represent alternative kinds of organizational learning which should interact within companies (March, 1991).

Exploration is generally associated to research and discovery of new strategic paths through which a competitive advantage may be generated in the long term, whereas exploitation is associated to an improvement of existing procedures and knowledge renewal, that should produce effects in the short-term. In management control terms, exploration occurs when managers are involved in decisions concerning the company strategy, whereas exploitation is used when taking decision at operating level. Ambidextrous

organizations need to balance long-term exploration and short-term exploitation in order to be successful over time (McCarthy and Gordon, 2011).

Lee and Widener (2016) show that a specific business intelligence system is associated with a specific organizational learning mode. We assume this to apply also for BD&A information. In particular, we intend to test whether the managers' perceptions about BD&A change when they are used in support of exploration or exploitation learning. Accordingly, we develop the following research question:

RQ2: Exploration and exploitation learning may influence the managers' perceptions about usefulness of BD&A.

In our research, we represent exploration through decisions process pertaining to the definition of a long-term strategy, whereas exploration is contextualized through short-term decisions.
Since BD&A generally refer to concepts that are broad, unstructured, qualitative, etc. we expect that managers may perceive them as more useful when used in support of exploration.

2.3 Managers' individual characteristics

Organizational learning and individual learning are strictly related (March 1991), consequently managers' individual characteristics are essential to get insights about how and why an information system is used in practice. A wide literature provides evidence that experience, skills, roles covered may influence organisational learning (Stelmaszczyk, 2016). As example, skilled managers, when involved in decision-making in those areas where they believe to hold a deep understanding and knowledge, may be subject to a cognitive inertia and consequently put an over-reliance on their past experiences, preconceptions and beliefs (Bertels, Koen and Elsum, 2015; Tripsas, 2009).

Kane and Alavi (2007) find that IT can act as enabler of individual learning mechanisms that can significantly contribute to the organisational exploration and exploitation. New information technologies may create an evolutionary environment that necessitate time for the human element to adapt to (Liu and Vasarhelyi, 2014). Previous cited studies provide us the motivation to include such variables in our research framework, aiming to discover whether the inclination of managers to adopt such kind of information may be associated to peculiar individual characteristics.

Beck et al. (2014) show that managers are reluctant to revise a decision even if they realize that a supporting information was biased. Considering that BD&A, particularly when obtained by collecting data from external and unstructured sources, may entail some risks of reliability is possible that not all managers will be willing to adopt them and their inclination could depend on their level of confidence with numbers or by previous experiences in adopting complex information (Kwon, Lee and Shin, 2014). Consistent with extant literature we develop the following research question:

RQ3: Individual characteristics may influence the managers' usefulness perceptions about different types of information, including BD&A.

Considering the wide number of factors that may condition the individual characteristics, we intend, in particular, to test the significance of the following factors: years of experience, level of "confidence with numbers".

In line with Bertels et al. (2015), we expect that managers with a longer tenure may feel sceptical in relying on BD&A, in favour of their personal preconceptions and beliefs and/or traditional accounting information. Conversely, confidence with numbers may act as enablers of individual inclination to adopt BD&A.

3. Description of explanatory variables and research methodology

To answer the research questions developed in the previous section, we collected data by a survey of 117 students and managers attending MBA post-graduate programs. The respondents are heterogeneous in terms of gender (62% male, 38% female), age, level of experience and confidence with numbers (see table 2).

Table 2: Descriptive statistics for respondents' sample

	Mean	Dev. Std.	Min	Max	Median
Age	33.4	8.6	22	59	31
Working Experience (Years)	9.8	8.4	0	35	7
Confidence with numbers (1-7)	5.9	1.4	1	7	6

The "confidence with numbers" is a measure which expresses the importance and frequency with which quantitative information daily supports the respondents' decision-making and has been assessed using a scale from 1 to 7 where 1 means "I never use numbers", whereas 7 means "numbers are essentials in my job".

Since the analysis aims to discover whether the operating context in which managers operate may affect users' perceptions, the questionnaire used to collect data has been structured by considering 6 situations in which managers are asked to take a decision, three of which are examples of decision processes at a strategic level and three are examples of decisions at operating level. As explained in the previous section, decisions at strategic level should require exploration learning to a larger extent, whereas exploitation learning is more likely to occur when taking decision at operating level. For each proposed situation, the respondents have been asked to assess the usefulness of a list of six predetermined information including two examples for each of the following categories: traditional management accounting information, BD&A, existing experience and information obtained through personal interactions with external players (customers, sales intermediaries, suppliers, etc.). The respondents evaluated the usefulness of information by using a score ranging from 1 (useless) to 7 (essential).

The decision processes and the list of information proposed in the questionnaire for each situation have been identified by interviewing 2 top-managers involved in strategic planning and 2 middle-level managers operating in two different manufacturing companies. Furthermore, the information items considered in every situation, classified by the three information categories, have been checked for internal consistency by using the Cronbach's alpha. The results were in all cases higher than 0.7 confirming that every category information is unidimensional.

For what concern the research methodology, we used a mixed between-within factorial ANOVA. Such a methodology is suitable when two or more independent variables (factors) are analyzed, which may produce effects directly by themselves and/or in interaction with each other (Heinrichs and Lim, 2003). Generally, a mixed factorial ANOVA is performed when the dependent variable is measured over several time points or from different perspectives ("time" and "perspectives" are the "within-subjects" factors) and simultaneously the subjects are divided into separate groups, according to some characteristics, such as "experience level" (these characteristics are the "between-subjects" factors). The aim is to estimate the main effects of the within- and between-subject factors on the dependent variable and to understand if significant interactions exist that may reinforce or attenuate the effect of each factor considered separately (Keppel and Wickens, 2004). The results of our ANOVA are discussed in the following section.

4. Discussion of results

A 3×2×2×3 mixed-factorial ANOVA was performed to examine the effects on the manager's usefulness perceptions produced by the following variables: years of experience (EXP), confidence with numbers (CN), organizational level (OL) and information categories (TYPE). EXP and CN are "between-subjects" factors, whereas OL and TYPE are "within-subjects" factors. EXP has been grouped in three levels corresponding to: no experience; low experience and high experience. The mean (calculated excluding respondents with no experience) is considered as threshold to categorize low and high experienced managers. Similarly, the respondents have been classified as low/high confident with numbers if the score was below/above the mean. The thresholds for OL and TYPE are described above.

Prior to the analysis, the Levene's test for equality of variances and the Mauchly's sphericity test were performed. The results indicated no violation of ANOVA's assumptions, except for OL*TYPE interaction (see Table A and B in Appendix). Therefore, the Greenhouse-Geisser test was used to correct data for this violation of sphericity. Table 3 shows the significance of main effects and interactions.

Table 3: Mixed factorial ANOVA: tests of between-within subjects factors effects.

Dependent variable: manager's usefulness perceptions

Effect	df	F	p-value
OL	1	1.432	0.234
OL*EXP	2	0.420	0.658
OL*CN	1	0.641	0.425
OL*EXP*CN	2	1.457	0.237
Error	111		
TYPE	2	2.702	0.069
TYPE*EXP	4	2.888	0.023
TYPE*CN	2	7.109	0.001
TYPE*EXP*CN	4	2.046	0.089
Error	222		
OL*TYPE	2	16.688	0.000[*]
OL*TYPE*EXP	4	0.620	0.649
OL*TYPE*CN	2	0.427	0.653
OL*TYPE*EXP*CN	4	0.601	0.662
Error	222		

* Corrected p-value, Greenhouse-Geisser ε = 0.8765.

None of the hypothesized main effects was supported (all p-values < .05). Conversely, significant interactions for TYPE*EXP (p-value = .023), TYPE*CN (p-value = .001) and OL*TYPE (p-value < .001) were detected.

Planned contrasts and post-hoc tests with Bonferroni corrections were performed to assess differences among means when significant effects were found.

For what concern the first research question (RQ1), the results suggest that the intrinsic characteristics of information by themselves do not produce a significant effect on managers' perceptions of usefulness.

Consequently, the expected issues about accuracy, timeliness, consistency and completeness (Hazen et al, 2014) do not result robust determinants of perceived data quality when considered as an isolate factor. Nevertheless, the TYPE factor is relevant when its interactions with OL and individual characteristics (IC) are considered. Figure 1 shows the Least Squared (LS) means for the OL*TYPE interaction (vertical bars denote 0.95 confidence intervals). The graph indicates that OL influences mangers' perceptions about BD&A.

The mean of usefulness perceptions about BD&A is higher in support of decision-making at strategic level, compared with those at operating level. Contrast analysis confirmed the statistical significance about the hypothesized difference (RQ2). Furthermore, OL produces a mediating effect also for traditional management accounting information which is considered much more useful when employed at operating level.

However, it's worth noting that in a strategic context, BD&A may compete with informal managers' knowledge since between the two categories of information, only a slight and non-significant difference exists. Further research may provide additional insights about this issue.
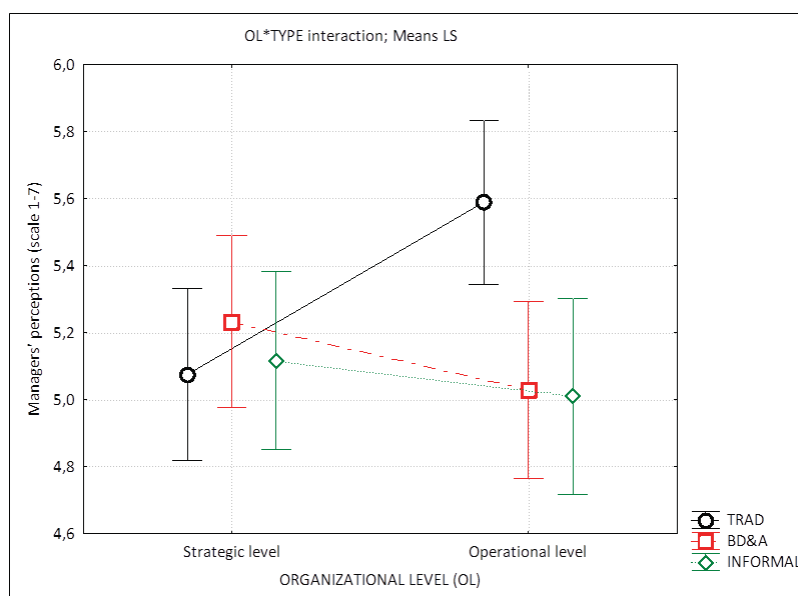
Figure 1: Plot of means (LS) for OL*TYPE interaction

Also some individual characteristics result to influence managers' perceptions about different types of information, including BD&A. For what concern high experienced managers, a significant difference exists in their usefulness perceptions between BD&A and all the other types of information. In particular, as hypothesized BD&A are considered less relevant (see Table 4).

Table 4: Planned contrasts of usefulness perceptions about different types of information for high experienced mangers

Contrast	Estimate	Std error	t	p-value
BD&A vs TRAD	-0,643	0,319	-2,018	0,046
BD&A vs INF	-0,704	0,296	-2,381	0,019

The planned contrasts do not support the role of "confidence with numbers" as enabler of BD&A adoption: the results in table 5 do not show a significant difference in the perceptions of BD&A usefulness for managers with high and low confidence with numbers.

Table 5: Planned contrast of managers' usefulness perceptions about BD&A for different levels of confidence with numbers

Contrast	Estimate	Std error	t	p-value
High confidence vs Low confidence	0,013	0,488	0,027	0,979

However, post-hoc tests with Bonferroni corrections show that the difference between BD&A and traditional management accounting information is significant for managers with higher confidence (see Table C in Appendix)

Surprisingly and contrary to our expectations, the results show that when managers are more used to support decisions with "numbers", they tend to be more inclined to rely on the set of information which they are confident with, i.e. the traditional management accounting information. The results are interesting in that sense and show some contradictions with extant literature (Kwon, Lee and Shin, 2014), which deserve additional research.

5. Conclusions

The present paper deals with information obtained through BD&A techniques with the intent to investigate the factors that may condition the inclination of managers to use them in support of decision-making.
Drawing on literature, we formulated hypotheses about three factors, which are expected to act in isolation or interacting one each other, namely: intrinsic characteristics, organizational level and individual characteristics.

We collected data through a survey of post-graduate students and managers attending an executive MBA program and a mixed between-within factorial ANOVA was performed.

We find that information is perceived as differently useful when employed at strategic rather than at operating level where exploration and exploitation learning are required respectively. In line with Lee and Widener (2016), we find that a management information system should be customized coherently with a specific set of decisions, for which a given organizational learning mode (exploration vs exploitation) is assumed to be required, and this apply also to BD&A.

Furthermore, managers' individual characteristics, in particular the years of experience and confidence in using information in support of decision-making may influence the managers' inclination to rely on BD&A.

As hypothesized, high experienced managers consider BD&A less relevant than other types of information. Additionally, even if the "confidence with numbers" doesn't influence managers' perception about BD&A, we find that managers confident in supporting decisions with "numbers", tend to be more inclined to rely on traditional information rather than on BD&A.

The results contribute to literature on management accounting systems showing that intrinsic characteristics of information do not condition managers' perceptions by themselves, but they do when considered in combination with the organizational learning mode and the managers' individual characteristics.

The paper also provides interesting managerial contributions. In particular, the results show that BD&A initiatives may be more successful when employed in support of strategic management.

Furthermore, pilot-tests or training initiatives may be suitable when BD&A are implemented in favour of managers with a longer tenure, which feel generally more confident in using traditional management accounting information or their personal preconceptions and beliefs.

The findings also put in evidence possible future directions for research. In particular, additional factors may be included among the individual characteristics, as example the effects produced by the previous experience in adopting more complex information on usefulness perceptions, while among the intrinsic characteristics, the source of data (internal/external) might also produce a significant influence.

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