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Managing complexity in knowledge-intensive manufacturing firms in big data era. The importance of internet of things and artificial intelligence

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ABSTRACT

Firms are by definition characterized by a high degree of complexity. Indeed, firms are complex systems whose success is strictly related to several different internal and external involved players and contexts. This is particularly true for knowledge-intensive manufacturing firms, which increasingly need huge amount of data and a wide spectrum of information flows spanning the whole organization. Hence the need to explore more deeply the impact of digital technologies on this category of firms. The aim of this research is to investigate whether and how information systems based on internet of things (IoT) and artificial intelligence (AI) may allow managers of knowledge-intensive manufacturing firms to better manage complexity.

Keywords: Knowledge Management; knowledge-intensive manufacturing firms; Complexity; Information Systems; Big Data; Internet of Things; Artificial Intelligence.

1. INTRODUCTION

According to the Viable Systems Approach (VSA), which is a managerial theory widely used to interpret firms as viable systems, a firm may be considered as a complex system formed by parts and relations whose existence is purposeful and thriving to achieve a situation of stability [17]. Yet, firms are not isolated systems, but interact with other systems belonging to the same environment such as other firms and policy makers. Additionally, firms themselves are formed by 'parts' (or sub-systems) organised around functions that aim towards a common goal, which is frequently represented by profit and success [1]. Firms, including small and medium sized firms [5; 6; 7; 9; 12; 13; 14], are indeed complex systems, then, managing a firm directly involves managing complexity. In other words, if managers are not able to deal with the increasing complexity characterizing a firm's context their actions will be very unlikely to drive the firm to success [6; 15]. In this perspective, VSA scholars assume that the complexity of a firm may be managed through a series of attempts aiming at finding an equilibrium between firms' capacities and objectives [19]. This approach is extremely similar to cyberneticists thinking about how to manage informatics systems. In fact, cyberneticists assume that the complexity of a system (usually an informatics system) may be managed through a circular process of interaction and interpretation. Hence, both VSA scholars and cyberneticists think that complexity may be reduced and managed by deconstructing complex systems (or actions) into smaller and more interlegible ones. This is the main touch point between management literature (and, in particular, VSA approach) and cybernetics literature.

Nevertheless, the traditional theoretical approach to complexity management is progressively showing its limitations in the current digital era. Indeed, the availability of new datasets, such as big data, has dramatically increased the degree of complexity that managers have to face every day: new data are related with increasingly complex knowledge flows, which are in turn related with the need to manage them in order to properly interpret the information that they contain [20]. Only if managers are able to make the right information flow available to the right actor, the firm will be able to react to environmental changes and to exploit its knowledge creation potential [4; 8]. This is particularly true for knowledge-intensive manufacturing firms -which are firms whose manufacturing processes continuity deeply rely on extremely specific technical knowledge [3], including that originating from external consultants [10; 11]. In particular, as this kind of firms usually use innovative-technologies-oriented production processes, they also need to design and use processes predisposed to collect, analyse, interpret and diffuse knowledge to all the involved players. Indeed, only if the right player receives the right knowledge flow, he/she will adequately contribute to the continuance of production processes.

Obviously, the availability of new datasets such as big data has dramatically digitalized the knowledge management processes and consequently increased their complexity. Hence, it emerged the need to investigate and conceptualize how internet of things (IoT) and artificial intelligence (AI) based techniques liable to process big data may ensure knowledge management and production processes continuance in knowledge-intensive manufacturing firms. Additionally, as these firms are typically characterized by high technology intensity, it can be expected that they have already started to exploit big data potential.

2. INTERNET OF THINGS, ARTIFICIAL INTELLIGENCE AND COMPLEXITY MANAGEMENT IN BIG DATA ERA

Internet of things (IoT) can be described as "the (current) advent of sophisticated networks of objects and items connected through the web, often equipped with ubiquitous intelligence [2, p. 348]". Differently, artificial intelligence (AI) has been identified as a form of intelligence that may be demonstrated by machines [18]. Hence, machines characterized by AI may almost autonomously act and decide how to optimize an action without human intervention. Therefore, the joint co-existence of interned of things and artificial intelligence may allow a machine to be connected through the web, exchange information and autonomously decide what need to be done [2; 13]. IoT is allowing production processes managers to modify production rates using digital inputs. The digitalization of inputs and information flows has also a side effect, which is the increasing of volume of data and their complexity [16]. In this perspective, the notion of internet of things has also been put in strict connection with the notion of big data. Indeed, big datasets (apart from usually being so large that they cannot be analysed with traditional software) treat data originating from machines autonomously ad/ or being automatically collected by machines on the web [21]. In this connection, AI based techniques such as machine learning allow analytics software to automatically adapt to different types of data and to "train" a machine to do a new task according to the information different types of data may contain [21].

Data complexity tends to increase as the diffusion of big data is increased. Furthermore, the integration of information systems based on IoT and AI analytics techniques may have several effects on firms. First, it may allow manager to better know the performances of production processes: IoT techniques allow to collect data from the machines, while AI analytics techniques allow to deconstruct data complexity [17]. Second, IoT allows production managers to send inputs to machines in any moment, thus continuously adjusting productive capacity and production processes [2]. Third, IoT spanning the whole organization allows managers to achieve a complete and up do date vision of the firm as a whole. From this it follows that IoT and AI may prove crucial in managing firms' complexity [20; 22; 23], especially in the case of knowledge-intensive manufacturing firms. Indeed, the more information managers get, the better they can influence the status and the physiology of firms' processes. Additionally, they can also continuously put new information in circulation within the organization, thus continuously increasing a firm's knowledge base. Finally, information systems based on IoT may better diffuse knowledge coming from machines to all the players involved in the production processes.

In this perspective, IoT and AI, if adequately integrated into production and information systems, may allow managers of knowledge-intensive manufacturing firms to better collect and analyse information, to make the needed knowledge available for the right player at the right moment, as well as to make the knowledge flows faster and to adapt in real time production rates and range, thus maximizing the contribution of each player to a firm's processes of adaptation to changing situation. Hence, the integration of IoT and AI in knowledge intensive manufacturing firms may generate several competitive advantages. As an example, such IoT and AI may cause increases in firms' capacity to identify and exploit new opportunities and, as a consequence, dynamism. Therefore, it may be possible to assume that IoT and AI may generically increase performances.

3. CONCLUSIONS

This exploratory research draft points out the need to better explore the role of IoT and AI for complexity management, with particular reference to knowledge-intensive manufacturing firms.

Being a brief draft, this paper doesn't provide any empirical analysis nor generalizable results. Rather, it suggests the need of future research investigating this emerging issue trough qualitative and quantitative methodologies and finding out potential suggestion for managers of knowledge-intensive firms. As an example, scholars should evaluate the possibility to develop frameworks based on qualitative evidences to test our hypotheses. Similarly, the authors recommend future scholars approaching the topic to survey a large pools of knowledge intensive manufacturing firms to provide evidences to our assumptions.

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