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ORIGINAL PAPER

IMPACTS OF BIG DATA ANALYTICS AND ABSORPTIVE CAPACITY ON SUSTAINABLE SUPPLY CHAIN INNOVATION: A CONCEPTUAL FRAMEWORK

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ABSTRACT. **Background:** Big data and predictive analytics could improve the ability to help with the sustainability of sourcing decisions. Sustainability has become a necessary goal for businesses and a powerful strategy for competitive advantage. There's a need for sustainable innovations along the supply chain to enable companies to have a strong market presence. Developing absorptive capacity both in firms and in supply chains are also integral to responding to dynamic markets and customer needs. The main objective of this paper is to identify the features of big data and predictive analytics applied to sustainable supply chain innovation, and to analyze the role of absorptive capacity.
Methods: A literature review investigates how absorptive capacity affects the impact of the utilization of big data and predictive analytics on sustainable supply chain innovation.
Results: This paper proposes a conceptual framework linking the different elements. It also proposes a synthesis of the existing definitions of the used concepts. In particular, the role of absorptive capacity as enabler on Big Data and Predictive Analytics on sustainable supply chain innovation is stressed.
Conclusions: The paper investigates the emerging paradigm of big data and predictive analytics. The conceptual framework use theoretical foundation of absorptive capacity, and the extant literature on Big Data and predictive analytics. This framework will help us to build a research model for sustainable supply chain innovation applications. Further work is required to develop an action research methodology for validating the framework in depth within a company.

Key words: absorptive capacity, sustainable supply chain innovation, big data, predictive analytics.

INTRODUCTION

Companies are constantly facing to do more with less. The pressure to reduce costs while at the same time enhancing performance is a consistent trend today. These challenges are crushing the profit margins and creating headaches for supply chain manager and organizations as well.

Added to this, a significant number of consumer goods firms and retail leaders also indicated the importance of sustainability in their plans through transparency and environmental considerations [Deloitte & MHI 2016].

These challenges are the motor of interest of this work. Researchers and practitioners should work together through collaboration to seek and invest in sustainable and innovative solutions.

This research aims to explore how big data and predictive analytics can affect sustainable supply chain innovations. Our inquiry is driven first by a state of the art of pertinent literature so that the existing body of knowledge in this area can be identified. Through a comprehensive analysis of the literature,

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salient theoretical constructs/variables that conceptually define the concepts and business practices of the sustainable supply chain innovation are identified.

To knuckle down this academic approach, we developed a conceptual framework that will help us to identify the main features and to explore definitions of the concepts involved.

LITERATURE REVIEW

Sustainability and the supply chain perspective

In 1987, the World Commission on Economic Development promoted the term 'sustainable development' in its well refers report as: "a development that meets the needs, of the present without compromising the ability of future generations to meet their needs [Butlin 1989]." This commission affirmed that sustainable development required the simultaneous adoption of environmental, economic, and equity principles. Unfortunately, the macroeconomic, societal definition of sustainability is difficult for organizations. The application of this provides little guidance regarding how organizations might identify future versus present needs. The determination of technologies and resources will be necessary to understand the effective balance between organizational responsibilities and the multiple stakeholders such as shareholders, employees, other organizations in the supply chain, and broader stakeholders including society and the natural environment [Bansal 2005].

On the contrary, the organizational definitions of sustainability in the engineering literature have been more encompassing, and have explicitly incorporated the social, environmental, and economic dimensions of the macro point of view. In this manner, its define organizational sustainability as, "a wise balance among economic development, environmental stewardship, and social equity" [Sikdar 2003].

There is a growing need for integrating environmentally sound choices into supply-chain management.

Reviews on sustainability in a supply chain or operational context have largely centered on a broad and strategic overview. The authors [Seuring & Muller 2008] define sustainable supply chain management (SSCM): "as the management of material, information, and capital flow as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social into account which are derived from customer and stakeholder requirements." Strictly speaking, to meet the requirement of sustainability practices in the supply chain, a company must be able to comply with the triple bottom line that was mentioned above. However, it is important to stress here that in the SSCM literature fails to capture all the three aspects. SSCM until now has been primarily focused just on economic and environmental aspects, and there is an under-explored around the social and human aspect of sustainability that's need to be explored in depth [Seuring & Muller 2008; Anne Touboulic 2015; Hassini et al. 2012].

Sustainable Innovations

René Jorna [2006] and Faber [2005] believe that sustainability in the environmental sense is always directly or indirectly connected to the way in which people possess and organize knowledge. In general, managing and making this knowledge operational takes place to organizations, firms, enterprise, and institutes. Innovation can mean that something already in existence is renounced or abandoned and something new replaces it.

Big Data and Predictive Analytics

Big Data and Predictive Analytics (BDPA) is defined as: "a holistic approach to manage, process and analyze data regarding high volume, variety, velocity, veracity, and value to create actionable insights for sustained value, delivery, measuring performance and establishing competitive advantages [Fosso Wamba et al. 2015; Gunasekaran et al. 2017]."

It has emerged as both a strategic and operational tool that may bring fundamental changes to supply chain sustainability and innovation [Wu et al. 2015; Waller & Fawcett 2013; Huisingh 2017; Zhao et al. 2017]. Big data and predictive analytics are one of the fastest evolving fields due to the convergence of Internet of Things (IoT), cloud computing, and fast-cycling mobile devices [Downes, Larry; Nunes 2013]. As stated by [Fawcett et al. 2011; Assink 2006], advances in information technology enabled the supply chain revolution. Nowadays, data is so easy to collect (e.g., RFID, barcodes, loyalty cards) and low-cost to store, that big data is enabling a new source of customer intimacy and competitive advantage. Big data and predictive analytics would be an opportunity to knuckle down some challenges that industry is facing (e.g., improve customer experience, making sense of large amounts of unused business data, improve inaccurate or misleading revenue forecast and models, focus on micro decisions, etc.). These shows big data and predictive analytics practical, relevant value. However, recently [Richey et al. 2016] empirically explored the perception of Supply Chain Managers about big data, and practitioners have recognized the Volume, Variety, Velocity and Veracity characteristics of Big Data, but there is no harmony attained regarding its definition. This author defines, BDPA capabilities in the context of Supply Chain Management (SCM) as: "The ability of organizations to collect and organize supply chain data from heterogeneous systems, distributed across organizational boundaries, analyze it either batch-wise or real-time or near real-time, and visualize it intuitively to create proactive supply chain system and support decision making".

While a few literature review papers are linking BDPA and Supply Chain [Wamba & Akter 2015; Addo-Tenkorang & Helo 2016; Arunachalam et al. 2017; Richey et al. 2016; Fawcett & Waller 2014], these reviews have not discussed the positive impact of BDPA on SCM performances in the innovation and sustainability context.

Absorptive Capacity

Absorptive Capacity (ACAP) of organizations is considered as complementary resource and enabler of BDPA [Sáenz et al. 2011; Wamba et al. 2017; Wang et al. 2015]. It can be argued that supply chain organizations need to possess all key capabilities to obtain value or wisdom from raw data. According to [Roberts et al. 2012; Wang et al. 2014; Arunachalam et al. 2017], ACAP is used by many researchers to explain organizational learning from a strategic management perspective. ACAP is a multi-level and multi-dimensional construct. It relates to the individual level to inter-organizational level and can have many interrelated capabilities. In supply chain context, the critical information needed to improve supply chain performances is mostly available in external sources [Dobrzykowski et al. 2015] not readily accessible for decision-making. Nevertheless, BDPA can provide critical information in real-time and highlight the organizational capabilities to acquire, assimilate, transform, and exploit the information and knowledge for commercial ends. Furthermore, firms with low absorptive capacity would find difficult to adopt innovative BDPA technologies, for example, Elasticsearch, Kibana, and Beats [Ebner et al. 2014; Elastic.com 2017]. Likewise, it can be argued that even if BDPA resources are well established at the organization level, it becomes obsolete when an organization does not exhibit absorptive capacity. Indeed, Absorptive Capacity is considered as one of the prerequisites of BDPA initiatives for a successful implementation [Kabir & Carayannis 2013]. However, many large firms still failing in developing implementation plans of this technology due to the lack of the right capabilities to support innovation [Čiutienė & Thattakath 2014; Assink 2006]. Academic research and reviews related assimilation as a capability that can impact positively supply chain performances [Hazen et al. 2016; Gunasekaran et al. 2017], but the influence of several organizational factors remains ambiguous [Oliveira et al. 2012; Schoenherr & Speier-Pero 2015; Gunasekaran et al. 2017; Arunachalam et al. 2017; Wamba et al. 2017]

and therefore this research seeks to address these missing link.

Supply Chain Innovation

The concept of Supply Chain Innovation (SCI) signifies an integrated change from incremental to radical changes in product, process, marketing technology, resource and organization, which are associated with all related parties covering all related functions in supply chain and creating value for all stakeholders [Arlbjørn et al. 2011]. Due to the adoption of ICT technologies, supply chains are enabled to monitor the information flow and inclined towards collecting and analyzing a variety of data for efficient management [Chae & Olson 2013]. A typical supply chain has to manage the inflow of more than 100 gigabytes of data every day [TheEconomist 2010]. In fact, about 90% of data that are available today was generated by humankind in the last couple of years [Fawcett & Waller 2014]. It is estimated that the use of RFID tags would increase rapidly to USD 15.84 billion by 2021 [Business_Wire 2017]. The number of networked sensors used in automotive, retail and transportation has increased at the rate of 30% per year [Brown et al. 2011; Manyika et al. 2013], with the perception that the sensor-based technology could substantially reduce the operational cost by 10–25% [Hahn & Packowski 2015]. The volume of digital data is growing exponentially and expected to reach 35 Zeta bytes by 2020 [Tien 2015]. In this infobesity scenario, companies are increasingly recognizing the value of advanced analytics tools. When properly applied, Big Data and Predictive Analytics tools can deeply influence the marketing, logistics, operations, and sourcing sectors of supply chain innovations. Marketing has the most developed analytics with the focus on customer demand and behavior; prices can be optimized and customer strategies can be adjusted dynamically. Logistics analytics optimize inventory and resource allocation, identify optimal distribution locations, and minimize transportation costs. Operations analytics measure productivity and quality in order to optimize maintenance and inventory. Sourcing has the least developed analytics of the four but represents the most important and fastest growing area as it is a company's largest sector in terms of expenditure; analytics here improve supplier negotiations and decrease tail-end spend [Columbus 2015; Sanders 2016]. Adoption of BDPA technologies could improve organization capabilities in today's rapidly changing dynamic market environment [Wang et al. 2015; Gupta & George 2016; Wamba et al. 2017]. Considering the emphasis on sustainability, and SC in recent years, some authors are mentioning that if it the Supply Chain Innovation (SCI) results in balanced performance of economic, social and environmental dimensions, in other words, all three dimensions of sustainability have positive innovation performance. It is called a Sustainable Supply Chain Innovation (SSCI) [Gao et al. 2017]. We put forward that there are several ways by which BDPA resources and outputs can be leveraged to increase sustainability in the supply chain. Research investigating the link between BDPA and sustainability in the supply chain is contemporarily relevant and is urgently in need of attention from both the academic and practitioner communities.

CONCEPTUAL FRAMEWORK

Our proposition is a conceptual framework that links performances and innovation. Also, these links include further elements as shown in Fig 1 below.

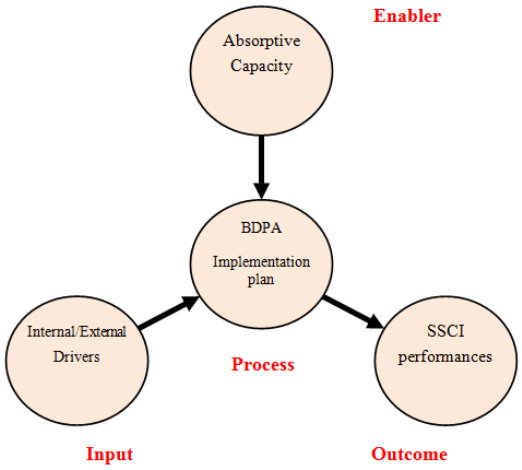

Fig. 1. Conceptual framework

The first element considers the drivers of the innovation [Walker et al. 2008; Lin et al. 2010]: these are the factors that motivate the adoption of supply chain innovation and sustainability. These drivers are described for any innovation explained before as well as for supply chain innovation and sustainability, and for this reason, they have been included in the conceptual framework. The identified drivers have been divided into two groups, according to the observations of [Walker et al. 2008; Lin et al. 2010]:

a) Internal drivers: There is a range of different organization-related supply chain sustainability management drivers. Personal commitment of individuals has been found to be positively related to supply chain sustainability [Walker et al. 2008]. According to this author to successfully drive sustainable supply chain practices, personal commitment and impetus have not necessarily resided at top-management level. In fact, the well known policy value champions were in staff positions. The existence of this policy the author explain that is necessary but insufficient condition for the deployment of environmentally friendly practices across a wider range of value chain activities. Another driver is the desire to reduce costs. Throughout a product life cycle, pollution reflects hidden costs in the form of wasted resources and effort. By embracing the concept of pollution prevention costs can be prevented. Environmental performance has been found to drive superior quality. An increased pressure from investors has also been observed in the development of environmental policies. In summary, organizations internal drivers fronting supply chain innovation and sustainability practices include the personal commitment of leaders, middle management, policy entrepreneurs, and investors. Internal organizational drivers include focusing on cost reduction through minimizing waste and pollution, often leading to quality improvements. These organizational factors include investor pressure, improve quality, employee involvement, desire to reduce costs, manage economic risk, values of the founder, skillful policy entrepreneurs [Walker et al. 2008].
b) External drivers: These elements involved the impact from external factors that included the following:
   i. Regulatory appears to be a strong driver for sustainable supply chain sustainability and innovation projects, particularly if companies are proactive and innovative in their approach to regulatory compliance (e.g., legislative and regulatory compliance, ISO 14000 certification).
   ii. Customers exert pressure on the organization to engage in sustainable practices (e.g., pressure by customers to SSCM, marketing pressures, collaborates with customers).
   iii. Competition as potential sustainable innovation leaders may be able to state industry norms or legal decree and so clearly have the ability to drive in sustainable innovation (e.g., gaining competitive advantage, improve firm performance).
   iv. The societal driver includes increasing public awareness, consumer demand for environmentally friendly performance, and the influence of NGOs concerned with corporate greenwash (e.g., public pressure, consumer criticism).
   v. Suppliers have not been investigated in depth. Exist a lack of research that identified suppliers as a driver. However, integration and collaboration in supply chain sustainability and innovation can support more effective sustainability issues (e.g., collaborate with suppliers, supply integration)

The second element considers the relevance of new technologies. Advances in information technology enabled the supply chain [Assink 2006]. Data sciences technologies such as big data and predictive analytics were chosen in the study because they are impacting many areas and are changing the rules of the game [Fawcett & Waller 2014]. Leveraging big data with predictive analytics have proven useful because they get us closer to definitions and predictions of individual consumer behavior [Waller et al. 2013]. Understanding the uses and implications of big data and predictive

analytics will be urgent because will disrupt traditional models of production, distribution, and demand obsolete in some products areas.

The third element considers the relevance of supply chain innovation and sustainability. The issue of sustainability in the supply chain is gaining attention in both academic literature and industry practice as an area of opportunity. Companies across geographic and industry boundaries are implementing sustainability initiatives in the supply chain in response to pressures from consumers, regions of operation, investors, and even employees. One of the key aspects of sustainability is the holistic view that was applied in understanding the total impacts of products and services and focusing improvements on areas with the most impact. A sustainable supply chain is one that includes measures of profit and loss as well as social and environmental dimensions [Carter & Rogers 2008; Linton et al. 2007]. Such a conceptualization has been referred by Elkington, 1997 to as the triple bottom line: financial, social, and environmental performance. SSCI until now has been primarily focused on economic and environmental aspects, and there is an under-explored around the social and human aspect of sustainability and innovation in business practices that have not been investigated in depth.

The fourth element considers the relevance of absorptive capacity which is presented by some authors, for example, [Helfat et al. 2007; Teece 2007; Mandal & Scholar 2011; Ulusoy 2003; Fainshmidt et al. 2016] as an enabling factor for innovation. By being an enabling factor, in this study absorptive capacity is presented as mediating factor on the relationship between disruptive innovation and the performances of sustainable supply chain inside the company. As a mentioned above, some studies are linking ACAP with sustainable supply chain practices, and ACAP influences in creating disruptive innovation [Beske 2012; Čiutienė & Thattakath 2014]. Despite all these studies, many large firms still fail to develop disruptive innovations due to the lack of the right capabilities [Čiutienė & Thattakath 2014; Assink 2006].

Our study to date has helped to identify some preliminary research questions that need to be addressed:

- How can SC managers use big data analytics to meet internal needs and adjust the changes in sustainability and innovation?
- How will big data analytics affect sustainable supply chain innovation design and operations on companies?
- How are companies complementing new technologies as big data and predictive analytics within absorptive capacity? And how do these adoptions affect their sustainable innovation performances?

CONCLUSIONS

In this paper the conceptual framework appears general enough to gather the main absorptive capacity as well as the key categories and supply chain innovation and sustainability performances for the firm. Through these considerations, we were also able to confirm the link between sustainability, BDPA, and absorptive capacity. As with any work, this study presents contributions and limitations. Firstly, this paper contributes to the supply chain innovation and sustainability literature and extends it by highlighting the role of Big Data and Predictive Analytics. Secondly, it provides a theoretical base for integrating the extant literature on absorptive capacity theory and dynamic capabilities within BDPA innovation concepts. The strongest possible limitation, as well as value of the present study, concerns the adoption of mixed method approach, which allows us just to formulate propositions and not to validate or reject them. The adoption of a single case study will give us the opportunity to develop further research to either increase the sample dimension or develop an action research methodology for validating the framework in depth within a real company.

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WPŁYW ANALIZY BIG DATA ORAZ ZDOLNOŚCI ABSORPCYJNEJ NA INNOWACYJNOŚĆ ZRÓWNOWAŻONEGO ŁAŃCUCHA DOSTAW: KONCEPCJA

STRESZCZENIE. **Wstęp:** Zastosowanie analizy big data oraz estymacji umożliwiają lepsze zrównoważenie decyzji wykorzystania zasobów. Rozwój zrównoważony stał się niezbędnym celem biznesowym i potężną strategią uzyskania przewagi konkurencyjnej. Można zaobserwować rosnące zapotrzebowania na zrównoważone innowacje w obrębie łańcucha dostaw, umożliwiające przedsiębiorstwom silny wpływ na rynek. Rozwój zdolności absorpcyjnej zarówno w firmach jak i w łańcuchach dostaw jest zintegrowane z potrzebami konsumentów oraz dynamicznych rynków. Głównym celem tej pracy było zidentyfikowanie cech analizy big data oraz estymacji istotnych dla zrównoważonych innowacji w obrębie łańcucha dostaw oraz analiza roli zdolności absorpcyjnej.
Metody: Podstawą pracy był przegląd literatury, umożliwiający analizę wpływu zdolności absorpcyjnych na zastosowanie analizy big data oraz estymacji dla osiągnięcia zrównoważonej innowacyjności w obrębie łańcucha dostaw.
Wyniki: Zaproponowano koncepcję rozwiązania łączącą różne elementy. Zaproponowano również syntezę istniejących definicji stosowanych koncepcji. W szczególności, rolę zdolności absorpcyjnych jako elementu umożliwiającego stosowanie analizy big data oraz estymacji dla zrównoważonej innowacyjności w obrębie łańcucha dostaw.
Wnioski: W pracy badano pojawiający się paradygmat analizy big data oraz estymacji. Koncepcja oparta jest na zastosowaniu zdolności absorpcyjnej oraz istniejących danych literaturowych i ich wpływu na analizę big data. Praca pomaga zbudować model badawczy dla zrównoważonych innowacji w obrębie łańcucha dostaw. Zwrócono uwagę na potrzebę kontynuowania badań w tym zakresie.

Słowa kluczowe: zdolność absorpcyjna, zrównoważona innowacyjność w łańcuchu dostaw, big data, estymacje.

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EINFLUSS DER BIG DATA-ANALYSE UND DER ABSORPTIONSFÄHIGKEIT AUF DIE INNOVATION EINER NACHHALTIGEN LIEFERKETTE: EIN KONZEPT

ZUSAMMENFASSUNG. Einleitung: Die Anwendung der Big Data-Analyse und der Schätzung ermöglichen eine bessere Nachhaltigkeit von Entscheidungen bezüglich der Ressourcennutzung. Die nachhaltige Entwicklung wurde zum unentbehrlichen Business-Ziel und zu einer gewaltigen Strategie für die Erzielung der Wettbewerbsfähigkeit.Es wird ein wachsender Bedarf an nachhaltigen Innovationen innerhalb der Lieferkette, die eine starke Beeinflussung des Marktes durch Unternehmen ermöglichen, beobachtet. Die Entwicklung der Absorptionsfähigkeit sowohl in Firmen als auch in Lieferketten ist mit Kundenbedürfnissen und dem Bedarf innerhalb dynamischer Märkte integriert. Das grundlegende Ziel der vorliegenden Arbeit war es, wesentliche Merkmale der Big Data-Analyse und der Schätzung der für nachhaltige Innovationen innerhalb der Lieferkette wichtigen Prämissen zu ermitteln und die Rolle der Absorptionsfähigkeit zu analysieren.
Methoden: Grundlegend für das Forschungsvorhaben war die Literaturübersicht, die eine Analyse des Einflusses von Absorptionsfähigkeiten auf die Anwendung der Big Data-Analyse und der Schätzung für die Erzielung einer nachhaltigen Innovation innerhalb der Lieferkette ermöglichte.
Ergebnisse: Es wurde ein unterschiedliche Elemente verbindendes Lösungskonzept vorgeschlagen. Dabei wurde auch eine Synthese der bestehenden Definitionen von angewendeten Konzepten ausgearbeitet. Das betrifft insbesondere die Rolle der Absorptionsfähigkeit als eines Elementes, das die Anwendung der Big Data-Analyse und der betreffenden Schätzung für die nachhaltige Innovation innerhalb der Lieferkette ermöglicht.
Fazit: Im Rahmen der betreffenden Forschungsstudie erforschte man das vorkommende Paradigma der Big Data-Analyse und der Schätzung. Das Konzept stützt sich auf die Anwendung der Absorptionsfähigkeit, ferner der bestehenden Fachliteraturangaben und deren Einflusses auf die Big Data-Analyse. Es hilft, ein Forschungsmodell für nachhaltige Innovationen innerhalb der Lieferkette aufzubauen. Es wurde auf die Notwendigkeit einer Fortsetzung von Forschungen in diesem Bereich hingewiesen.

Codewörter: Absorptionsfähigkeit, nachhaltige Innovation in der Lieferkette, Big Data-Analyse, Schätzungen

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