Technological Forecasting & Social Change xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda

Charbel Jose Chiappetta Jabbour[a,*], Ana Beatriz Lopes de Sousa Jabbour[a], Joseph Sarkis[b], Moacir Godinho Filho[c]

[a] Montpellier Business School, Montpellier Research in Management, 2300, Avenue des Moulins, 34185 Montpellier, Cédex 4, France.
[b] Foisie Business School, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609-2280, USA
[c] UFSCar - Federal University of São Carlos, Department of Industrial Engineering, Rodovia Washington Luiz Km 235, CEP 13565-905 São Carlos, Brazil

ARTICLE INFO

Keywords:
Circular economy
Large-scale data
Big-data
Sustainable operations
Sustainability
Stakeholders
Smart manufacturing

ABSTRACT

This work makes the case for the integration of the circular economy (CE) and large-scale data (LD), also known as big data. The paper is one of the first to integrate conceptual and practical trends regarding: (a) the ReSOLVE based models of the circular economy; (b) key stakeholders roles in pursuing a more sustainable society; and (c) the volume, velocity, variety, and veracity (4V's) of large-scale data (LD) management. This study's contributions include: (1) introducing a new integrative framework to enhance the understanding of the CE-LD nexus; (2) a relational matrix which illustrates the complexity of large-scale data and stakeholders management; and (3) a research agenda, with clear research propositions and future research direction. The proposed CE-LD integrative framework provides socio-technical insights for academics, practitioners, managers, and policy decision-makers.

1. Introduction

Large-scale data can positively influence and advance sustainable management (Dubey et al., 2018). This study makes the case for the integration of the circular economy (CE) –represented by the ReSOLVE model (The Ellen MacArthur Foundation, 2015) – and large-data (LD), 'big data' management. These two disparate fields have many synergistic relationships that can foster advancement in both fields; and also provide a perspective to enhance social and environmental sustainability.

The circular economy (CE), which is the integration of economic activity and environmental wellbeing (Murray et al., 2015), has emerged as one of the most relevant contemporary trends of the society (Pomponi and Moncaster, 2017). The circular economy is designed to eliminate waste through cycles of assembly, use, disassembly and reuse, with virtually no leakages from the system in terms of disposal or even recycling (Spring and Araujo, 2017). CE can also decouple environmental burden from economic growth; an important 'green growth' dimension (Vazquez-Brust et al., 2014).

CE has increasingly attracted attention from a variety of stakeholders (Geissdoerfer et al., 2017), driving knowledge and skills towards a more sustainable society (Genovese et al., 2017). CE, as a body of knowledge, is in its infancy (Bocken et al., 2017) and circular economy new business models (CENBM) have only emerged gradually (The Ellen MacArthur Foundation, 2017). There are significant scientific, research, and practical challenges and opportunities related to CE (Song et al., 2016).

CE is difficult to pursue effectively without a comprehensive discussion of supporting mechanisms and enablers. Information and large-scale data (LD) need to be an integral aspect of this discussion (Nobre and Tavares, 2017). Unlocking CE's potential depends on innovative large and complex dynamic data collection and analysis (Despeisse et al., 2017). Sharing data with stakeholders is also a critical dimension (Genovese et al., 2017). CE also depends on developing new business models, which include the ReSOLVE model pillars: use of regenerated materials, shared products, optimised production systems, closed loop strategies for end-of-life products, and emerging trends such as virtualisation and exploration of cutting-edge and disruptive technologies (The Ellen MacArthur Foundation, 2017).

Both CENBM and LD are innovative, emerging topics attracting considerable attention from academics, industry, policy-makers and other key-stakeholders in the transition to a sustainable society (Nobre and Tavares, 2017). While both fields of study have been widely discussed in disparate literature (Nobre and Tavares, 2017), their integration has seen limited study (Despeisse et al., 2017). CENBM and LD provide unique synergies; especially given that information is a key

* Corresponding author.
E-mail addresses: c.chiappetta-jabbour@montpellier-bs.com (C.J.C. Jabbour), a.sousa-jabbour@montpellier-bs.com (A.B.L.d.S. Jabbour), Jsarkis@wpi.edu (J. Sarkis), moacir@dep.ufscar.br (M.G. Filho).

http://dx.doi.org/10.1016/j.techfore.2017.09.010
Received 22 June 2017; Received in revised form 28 August 2017; Accepted 10 September 2017

CE enabler (Genovese et al., 2017). This integration becomes more relevant as managing large amounts of data is a key organisational success factor; especially with the evolution of the 'internet-of-things', cyber and smart industry integration (Tien, 2013; Wang and Song, 2014; Watson et al., 2010; Wu et al., 2014).

There are many challenges and difficulties in managing CE information and data (Ritzén and Sandström, 2017). This perception is aligned with a broader discussion of the critical role played by information systems in promoting truly sustainable organisations (Dao et al., 2011; Fiorini and Jabbour, 2017; Gholami et al., 2013; Melville, 2010; Sarkis, 2003; Sarkis et al., 2013). LD affects a broad range organisational and commercial concerns including manufacturing (Dubey et al., 2016), supply chain management (Papadopoulos et al., 2017a) and training (Dubey and Gunasekaran, 2015), all generating a number of implications for 21st century best practices management (Papadopoulos et al., 2017b).

A better understanding of CENBM-LD integration can occur through thoughtful frameworks that are comprehensive, logical, feasible and evaluated from a scientific research perspective. Relationships that defines how LD can be developed to support the six-main circular economy's business perspectives of the ReSOLVE model (The Ellen MacArthur Foundation, 2017) is one such framework. This framework addresses a gap that emerges from the profound scarcity of academic works seeking a better understanding of CE-LD integration (Nobre and Tavares, 2017). For instance, precise information on a variety of environmental impacts caused by products is crucial for CE (Elia et al., 2017; Lieder and Rashid, 2016).

The motivation for this research can be expressed as: which framework could portray and capture the complexity of the relationships between CE and LD? Consequently, this work introduces an innovative framework to integrate CE and LD. The proposed framework informs future research at the nexus of CENBM and LD. The ReSOLVE model (The Ellen MacArthur Foundation, 2017) is considered as an integral element of this framework due to its insights on how organisations can fully develop and contribute to a circular economy.

This study is unique because it: (a) integrates the The Ellen MacArthur Foundation's ReSOLVE framework (2015, 2017) for circular economy business models with LD. This relationship integrates two socio-technically critical topics for a more sustainable society (Nobre and Tavares, 2017); (b) provides an analysis of the current knowledge gaps regarding in CE-LD integration; and (c) proposes a research agenda for CE-LD integration to inspire researchers, practitioners, and policy makers, enabling full CE-LD integration. Recent systematic literature reviews on large data (for instance Mishra et al., 2017) and CE (Geisendorf and Pietrulla, 2017) have not identified any study that addresses this critically important sustainable society issue.

Methodologically, this work addresses the literature gap on the integration between CE-LD. Although the study may be classified as gap-spotting research (Alvesson and Sandberg, 2011; Sandberg and Alvesson, 2011); the resulting framework and assumptions set an important foundation for future research contributing to the sustainable operations body of knowledge. A conceptual framework is an articulation of ideas (Coll et al., 2005) that encapsulates a simplified and systematised view for relationships among complex concepts and contexts (Jabbour and Santos, 2008). The framework proposed in this research can inform future developments in research fields such as sustainable operations, the stakeholder theory, LD management, and CE policy.

After this introduction (Section 1) a theoretical background (Sections 2 and 3) on the circular economy (CE) and large-data (LD) is presented. Section 4 presents the potential links between the fields and present research propositions for future studies. Section 5 highlights implications for a variety of potential beneficiaries interested in this work.

2. Circular economy

A linear economy is based on developing and meeting demands while neglecting the fact that natural resources are finite (Ghisellini et al., 2016). The structure of "Take–Make–Use–Dispose" (Stahel, 2016) has governed most production systems internationally (Lieder and Rashid, 2016). To reverse this unsustainable economic structure various regions of the world, China and the European Union for instance, have supported policies to encourage CE principles (Ghisellini et al., 2016).

Although there are different views on CE (Geisendorf and Pietrulla, 2017), the circular economy encapsulates recapturing value of post-consumption products, resources, and packaging by swapping linear material and energy flows with circularity through closed-loop production and consumption systems. CE requires the development of new business models to enhance resource use value.

The biogeochemical and technical cycles can characterise CE (Murray et al., 2015). The biogeochemical or biological cycles address a reduction in the extraction of natural resources and management of flows of renewable resources. Technical cycles aim to apply the 3Rs - Reduce, Reuse, and Recycle - to recapture value of waste by circulating the waste across supply chains as a source of raw materials.

The biogeochemical and technical cycles are driven by three principles (The Ellen MacArthur Foundation, 2015): (a) control the balance between finite stock and renewable resource flows; (b) circulate the use of materials, components, and products; and (c) minimise negative externalities of production and consumption systems by applying new business models. CE complexity impacts not only organisations and their supply chains, but also governments by re-shaping the industrial and sustainability policy debate (Geng et al., 2013; Geng et al., 2016; Geng and Doberstein, 2008; Park et al., 2010; Stahel, 2016).

ReSOLVE is a framework developed to guide organisations in the transition to a circular economy (The Ellen MacArthur Foundation, 2015). ReSOLVE proposes six CE-based business model development strategies: (The Ellen MacArthur Foundation, 2015):

- **Regenerate** – This model focuses on a shift to renewable energy and material. Biological cycles circulate flows of energy and materials and convert organic waste into sources of energy and raw material for other chains.
- **Share** – This model has a shared economy perspective in which individuals share goods and assets; and ownership loses importance. Products are designed to last longer, and maintenance focuses on reuse of products and extending their life. Coordination between individuals is necessary for model viability. The "internet of things" can facilitate asset sharing (The Ellen MacArthur Foundation, 2015).
- **Optimise** – This model is technologically centred. Organisations use digital manufacturing technologies, such as sensors, automation, radio-frequency identification (RFID), big data, and remote steering to reduce waste in production systems and supply chains. Organisations benefit through a performance improvements; for instance, predictive maintenance schemes can be planned using real-time data (The Ellen MacArthur Foundation, 2015).
- **Loop** – This model uses biological and technical cycles. Biological cycles, for example, anaerobic digestion, can recapture the value of organic waste. Technical cycles can restore the value of post-consumption products and packaging through repair, reuse, remanufacturing, and recycling activities. Collaboration and coordination in supply chains is essential to close the loop and convert waste into useful resources. The use of intelligent devices, physical objects that are able to sense, record and communicate information about themselves and their surroundings for instance, provide information on location, condition, and availability of post-consumption products; supporting the loop strategy (The Ellen MacArthur Foundation, 2015).
- **Virtualise** – This model is a service-focused strategy. This model replaces physical products with virtual and dematerialised products