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Technological innovation for sustainable growth: An ontological perspective

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ABSTRACT

Technological innovations are seen as means to optimize the efficient and clean use of vital resources in social-biological-economic systems. However, partial theoretical perspectives and experiences of their effects can lead to significant oversight of their potential and limitations. There is a need to manage technological innovations for sustainable growth from a holistic perspective, systemically and systematically. To do so, we present and validate an ontological framework, map the current body of knowledge, and identify the emphases and gaps in the domain. The ontological framework is constructed from the common terminology of the domain. The analysis is based on a map of 375 research papers published in the most prestigious journals relevant to the domain. The results show significant gaps in the research to fulfil the potential. Future research can be directed to fill these gaps.

1. Introduction

Humanity faces an increasing and urgent need to manage scarce, natural, and vital man-made resources, such as ecology, energy, agriculture, healthcare, transportation, housing, education and many others, in the scenario of population increases and natural resource over-exploitation (Coccia, 2014; Harrison, 1998; Huesemann and Huesemann, 2008). Technological innovations are being developed in different fields to optimize the use of these resources in societies pursuing socioeconomic growth (Ayres, 1996; Jacobsson and Johnson, 2000; Tsoutsos and Stamboulis, 2005) and targeting sustainable development in bio-ecological and societal terms. The technological innovations are new means for the efficient, clean and optimal use of scarce resources (Klewitz and Hansen, 2014; Rennings, 2000). While the term sustainable development or sustainable growth was first coined at the United Nations Conference on the Human Environment in 1972 (Hall et al., 2010), the opportunities to innovate for sustainability garnered wide attention with the Brundtland report in 1987 (Eteokleous et al., 2016; Farahani et al., 2014; Govindan et al., 2014; Lukman et al., 2016), which noted the importance of firms to create, redesign, adapt, and diffuse environmentally sound technologies (WCED, 1987). In addition, this interest in the subject can be observed in the development of academic conferences on the subject. Examples of this are the IAMOT 2015 and 2016 conferences, which focused on issues concerning Technology, Innovation and Management for Sustainable Growth. Among the areas or research interests which are most studied the following stand out: Technological planning, social impact of technology, measurements Intellectual property, Industrial and manufacturing system technologies, Information and communication technology management Innovation and sustainable growth, Innovation, Education & e-learning, Management of biosciences and medical technology Management of innovation, Managing energy technologies, Managing green technology, technology and social incubation, transfer and entrepreneurship Social and technology policies, Sustainable logistics and supply chain management, foresight and forecasting Technology and globalization, among others.

This interest, which manifested in technological innovations for sustainable growth, emerged from different areas of knowledge, such as entrepreneurship, energy, policy, economics, sociology and engineering. Each has approaches, models, frameworks, and biases to study the challenges of sustainable growth. Their partial perspectives and lenses generate new knowledge in their own domains, but they are not necessarily compatible and complementary in a more holistic perspective (Hall et al., 2010). For example,

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technological innovations to use green energy or other sustainable technologies in manufacturing could be disconnected from cultural growth; the results may be constrained if appropriate educational and cultural catalyzing forces are not incorporated as part of the sustainable innovation strategy with customers and employees (Nanda and Singh, 2009). The emergence of a new knowledge area, such as the management of technological innovation for sustainable growth (MOTISG), is expected to derive from different disciplines, with the requirement of an understanding to define and develop a new discipline. In this context, connections and disconnections between research topics will affect the domain's agenda and, therefore, the harmonic development of policies and MOTISG (Nielsen et al., 2015).

The evolution of a complex domain, such as MOTISG, cannot be accomplished by simple inspection or analysis of its constituent elements. The complexity of the domain is combinatorial. It is necessary to systematically synthesize the domain knowledge, comprehensively orchestrate the efforts of the policy makers and practitioners and continuously monitor the consequences of the decisions made and actions taken. To understand, assess, plan, manage and monitor the effectiveness of strategies, policy or practices from a holistic perspective, a systematic and systemic approach is required. Thus, this paper is motivated by the need to find a holistic and comprehensive means to understand the complexity of the phenomena and design a multi-purpose and actionable tool to manage it. The central research questions of this study are as follows: a) How can one visualize MOTISG such that it allows for the analysis and synthesis of the field? b) What are the current emphases or gaps in the available knowledge? and c) How can one develop a roadmap of research to advance the domain?

To address these research questions, this paper presents an ontological framework for visualizing the combinatorial complexity of MOTISG in structured natural English. This paper then presents maps of the elements and themes of the framework that were heavily emphasized, lightly emphasized and not emphasized in the research of this domain between 1988 and 2014. Last, this paper discusses the potential reasons for and the consequences of the differences in emphases and suggests a roadmap for future research. The roadmap can be used to align the efforts of researchers, policy makers, and practitioners of MOTISG to satisfy the agendas of national innovation systems.

Many recent papers have highlighted the importance of governance and a variety of stakeholders in MOTISG (Husted and Sousa-Filho, 2017; Kang and Hwang, 2017; Niesten et al., 2017; Ramos et al., 2015; Zhu et al., 2017). These papers also propose different techniques for addressing the complexity of the domain (Disterheft et al., 2016; Uygun and Dede, 2016). The ontological framework proposed in this paper will help govern the stakeholders' competing and converging interests in MOTISG by visualizing them as part of a complex, open, socio-technical system with feedback.

2. Theoretical framework

According to Evans et al. (2017), little is known about the successful adoption of sustainable business models. When considering business model innovations for sustainability, this leads to a higher complexity related to how to preliminarily assess the impact of the sustainability innovations and how to understand their effects on the whole business network. In that sense, Edgeman and Eskildsen (2014) state that long-term firm success is a consequence of balancing both the competing and complementary interests of stakeholder segments, including society and the natural environment, in order to increase the likelihood of sustainable competitive positioning.

An interesting model used to understand the interactions between technological innovation and sustainable growth is under the view of the triple bottom line (Hart and Milstein, 2003; Schaltegger et al., 2012; Stubbs and Cocklin, 2008) where businesses must consider the co-creation of profits, social and environmental benefits and the balance among them, if they want to develop technological innovation for sustainable growth.

The sustainable value of businesses can be structured in three dimensions:

- *Environmental value forms*: Renewable resources, low emissions, low waste, biodiversity, pollution prevention (air, water, land).
- *Social value forms*: equality and diversity, well-being, community development, secure livelihood, labour standards, health and safety.
- *Economic value forms*: profit, return on investments, financial resilience, long-term viability, business stability.

For Gulati and Kletter (2005) the triple bottom line model means that "leading companies are transforming these relationships by taking a wider and longer-term view, which enable the move from a transactional mindset towards the development of trust-based, mutually beneficial and enduring relationships with key internal and external stakeholders " (as cited in Evans et al. (2017) (employees, suppliers, consumers and shareholders/investors; media; governments, universities, communities, internal organizations or local and international non-governmental organizations).

2.1. Environmental dimension

Climate change over the last few decades is evidence of the environmental degradation caused by humans pursuing economic development and of a growing population that overexploits natural resources and overestimates its technological achievements while ignoring its limitations (Bertinelli et al., 2012; Clow, 1998; Coccia, 2014). The environmental effects caused by the economic activities that consume natural resources is only one of the problems that researchers foresee leading to the collapse of social-biological-economic systems during the second half of the 21st century (Tsiliyannis, 2014). Ayres (1996) posed several questions about the kinds of technological innovations that would be needed for a truly sustainable future, highlighting that welfare may not be explained only and directly by economic growth but also by scientific and technological progress. Regarding the environmental dimension of sustainability, an eco-innovation perspective emerges as a response to the need to reduce the quantities of resources and sinks used via the incorporation of new and different technologies rather than by the novel use of old technologies (Huber, 2000). Research on sustainable innovations has expanded rapidly to increase understanding of the means by which new clean technologies (Montalvo, 2008) and social practices, such as eco-innovation (Hall and Clark, 2003), foster technological, institutional and organizational changes to the knowledge base of existing production systems to enable societies to become more sustainable. However, despite expanding knowledge, the eco-innovation concept reveals the tension among the rationales behind the economically oriented goals, ecological modernization and societal functions (Coenen and Díaz López, 2010).

2.2. Social dimension

Regarding the social and economic dimension of sustainability, companies are rethinking their relationships with key stakeholders who live in the environments in which they operate. Business