Eco-Innovations: Kick-Starting the Circular Economy

Wladmir Motta, Brazilian Institute of Information on Science and Technology, Brazil
Patricia Prado, University of York, United Kingdom
Liz-Rejane Issberner, Brazilian Institute of Information on Science and Technology, Brazil

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Abstract:
The generation of goods and services depends on the use of natural resources and generates discards throughout the productive process. The current economic model based on overproduction and overconsumption caused global warming and the growing depletion of natural resources. Deteriorating living conditions on the planet made discussions on sustainability and environment become an urgent issue. Among other actions from different agents, this context requires companies to adopt radical innovative ways of producing. Reviewing industrial practices is now a crucial element to disclose the areas where the innovative efforts must focus. Circular economy emerges as an alternative to the current linear approach, in which resources are used and discarded as if the planet had unlimited capacity to provide new sources of resources and absorb pollution. It is a way of (re)organising economic activities through a "resource-production-resource-regeneration" feedback vector. The concept may lead to a new circular production system where there is minimal waste, since all discards would potentially serve as input for a new productive cycle. The challenge of circular economy is to develop an innovative approach to overcome the current trade-off between our model of incessant economic growth and the environmental crisis. In this context, could eco-innovations contribute to build this approach? How could the implementation of eco-innovative practices by firms change the current linear approach? The present study aims to shed light to this discussion through a literature review analysing the generation of eco-innovations to stimulate the circular economy.

Keywords: eco-innovation; circular economy; sustainability; environment; ecological crisis.

1. Introduction

Human activities have vastly caused negative impacts on the environment on all scales. In the last decades, disturbing evidence has shown that both developing and developed industrial countries are critically deteriorating the ecological system that underpins all life on Earth (WWF, 2016; UNEP 2010). The current mode of production and consumption has generated an ecological crisis with devastating consequences to the planet and human societies, such as global warming, depletion of natural resources and declining biodiversity (Issberner & Léna, 2016; Latouche, 2012; Léna, 2012; UNEP, 2011, 2012). As the human population is drastically increasing, the circumstances are becoming even more critical and challenging. The UN Department of Economic and Social Affairs has just published its "World Population Prospects: The 2017 Revision" in June, estimating a population growth to 8.6 billion in 2030 and to 9.8 billion in 2050.

Coupled with the world population growth, more three billion middle-class consumers are expected to enter the global market by 2030 (World Economic Forum, 2014). This rise will generate an unparalleled demand for goods and services and for a finite supply of natural resources if the population keeps the same consumption patterns. The UN Sustainable Developmental Goals anticipate that the equivalent of almost three planets will be required to sustain the current lifestyles of the linear 'take-make-dispose' economy. According to Léna (2012), while the limits for the physical expansion of the economic system and the degradation generated were not noticeable, however there were crises, the belief that the system would provide what is needed for the growing consumption remained unshaken. This notion also hides an assumption that the planet has an endless capacity of recovering from its natural losses (Motta, Prado & Issberner, 2015). However, obvious signs of depletion of a large amount of natural resources, which may destabilise the operation of the current production system, started to raise distrust and suspicion on the current model (Wagner, Sullivan, & Sznopek, 2002). Despite the difficult scenario, the enthusiasm for changes is not commonplace, a good perspective is the Paris Agreement on climate change with its promises of radical transformation in technologies, investments and modes of consumption.

In the meantime, several studies have been questioning the current predominantly linear economic system (Andersen, 2007; Bonciu 2014; Greyson 2007; Lieder & Rachid 2016; Preston, 2012) based on extraction-production-consumption-discard/waste. This process prioritises economic objectives, with little or no regard for the environmental or social impacts generated at each stage. The natural resources depletion – but also its impacts in the prices volatility across the global economy – shed light to the need for a new economic model. In this context, circular economy has strengthened, as a concept but also as a practice. In search for improving their resources performance, many businesses tried to reuse products or their components and recover the material, energy or inputs used in their production processes (World Economic Forum, 2014). In doing so, they tried to change to an industrial model that decouples revenues from material input. In this sense, a circular economy is understood as an industrial system that is restorative or regenerative by intention and design (World Economic Forum, 2014). It is a proposal whose basic concepts were presented by Boulding (1966) and received theoretical contributions of industrial ecology. The circular economy aims to maximise the sustainable use of natural

resources seeking to minimise waste and organise economic activities considering a continuous process of refeeding (resource-production-regenerative resources). The concept may lead to a new production system where there is minimal waste, since all discards would potentially serve as input for a new productive cycle.

This new production system needs an innovative approach. However, technological innovations cannot always address ecological problems. As stated by Veiga and Issberner (2010, p. 114), "the innovations, particularly the technological ones, are part of the solution. But they have also been part of the ecological problem", as innovation has been oriented to competiveness achievement, not towards environmental issues for a long time (Prado & Issberner, 2016). In the last decade, though, private sector has been required to invest in technologies that can improve aspects such as energy and water use, reduction of emissions, management of natural resources and waste, among others (Freeman, Harrison, Wicks, Parmar, & de Colle, 2010; Zollo, Cennamo, & Neumann, 2013). This investment allows firms to reduce costs and enter into new markets for ecological products and services. On the other hand, firms have increased their commitment level towards environmental sustainability as a way to contribute to their short- and long-term value. (MIT, 2011; McKinsey, 2011). In doing so, these firms have been developing eco-innovations - innovations aiming to minimise the negative impacts on the environment and to reduce the use of natural resources.

It is necessary to understand the process of generation and adoption of eco-innovations for a sustainable life on the planet in a broader perspective. It is a crucial condition to face the ecological crisis. Reviewing industrial practices becomes an essential element to reveal the areas where eco-innovative effort should focus. The challenge of circular economy is then to develop an innovative approach to overcome the current trade-off between our model of economic development and the environmental crisis. In this context, could eco-innovations contribute to build this approach? How could the implementation of eco-innovative practices by firms change the current linear approach? The present study aims to shed light to this discussion through a literature review analysing the generation of eco-innovations to stimulate the circular economy.

2. Circular economy

In recent years the concept of circular economy has received increasing attention worldwide, but its origins are far from the last century. It has originated from various schools of thought and theories that challenge the prevailing economic system based on overconsumption leading to the finiteness of natural resources (Rizos, Tuokko, & Behrens, 2017). The ideals and foundations underlying circular economy had already been put forward, but its first formal use as a concept was made by Pearce and Turner (1990).

Various disciplines, authors and reports collaborated and influenced the construction of the circular economy as a concept. The industrial ecology brings the notion that the natural ecosystem and man-made industrial system operate in a similar way and are characterised by flows of materials, energy and information (Erkman, 1997; Ehrenfeld, 2007; Garner & Keoleian, 1995; Rizos et al., 2017). The cradle-to-cradle design demonstrates the need to maintain and even enhance the value, quality and productivity of material resources in order to have a net positive environmental effect

(Braungart, McDonough & Bollinger, 2006; Ankrah, Manu & Booth, 2015; Mcdonough & Braungart, 2002; Rizos et al., 2017). The blue economy introduces the idea that innovation is a fundamental lever in guiding businesses towards a transformation of practices influenced by the design and functions of natural ecosystems (Pauli, 2010; Rizos et al., 2017). Besides, there are also the 'limits to growth' proposed by the Club of Rome in the 1970s; the 'spaceship earth' metaphor presented by Barbara Ward and Kenneth Boulding also in the 1970s; and the steady state proposal by the eco-economist Herman Daly at the end of the 1970s.

Aiming to maximise resource efficiency, the circular economy represents an alternative to the current linear 'take-make-use-dispose economic' model. The central theme of the new concept is the valuation of materials within a closed-looped system, which involves other subjects such as: eco-innovation, eco-efficiency, eco-design, cleaner production, life cycle management, reverse logistics, and cleaner energy among others.

The concept of circular economy organises economic activities through a feedback vector (resource-production-regeneration of resources) and seeks to maximise the sustainable use of natural resources, eliminating waste. It can be understood as an alternative to the current and predominant system, where resources are used for a purpose and then discarded (linear economy). From a circular economy perspective, there is 'virtually' no concept of waste, as everything would be used as an input for a new productive cycle. This view is inspired by biological cycles, emphasising the importance of optimising the use of natural resources in a system over time (Di Maio & Rem 2015; Ellen Macarthur Foundation, 2013a and b; World Economic Forum, 2014).

Due to different subjects it addresses, the circular economy is a multidisciplinary field with the purpose of fostering a shift towards a more sustainable society. It relies on three fundamental principles: (1) preserving and enhancing natural capital by controlling finite stocks and balancing renewable resource flows; (2) optimising resource yields by circulating products, components, and materials at the highest utility and value at all times within technical and biological cycles; and (3) fostering system effectiveness by revealing and designing out negative externalities (Ellen Macarthur Foundation, 2013a).

According to Rizos et al. (2017), the main processes of a circular economy involve: 1) use of less primary resources throughout recycling, efficient use of resources and utilisation of renewable energy sources; 2) maintenance of the highest value of materials and products throughout product life extension and refurbishment, remanufacturing and re-use of products and components; 3) change of utilisation patterns throughout product as service, sharing models and shift in consumption patterns.

The shift toward a circular economy will require radical changes in the current mode of production and consumption, so that both producers and consumers as well as all stakeholders in the value chain will have a significant role to play (Mendoza, Sharmina, Gallego‐Schmid, Heyes & Azapagic, 2017). Effective implementation requires a systemic change involving innovative transformational technologies such as non-technological innovations. Together with the application of circular economy

concepts, they can radically reshape the process across the life cycle of products and drive fundamental changes across entire value chains that are not restricted to specific sectors or materials (Bicket et al., 2014; Acsinte & Verbeek, 2015; Accenture, 2014; Rizos et al., 2017; Ghisellini, Cialani & Ulgiati, 2016; Mendoza et al., 2017; Ellen MacArthur Foundation, 2013a).

3. Eco-innovative Approach

Environmental impacts and biodiversity losses caused by the traditional linear production model have gained visibility in economic and political discussions at a global level. In this context, the role played by innovation and technology are questioned as they have been driven towards competitiveness with little or no regard to the negative effects on the environment. For many years, innovation has been oriented to economic growth, productivity improvements and add value to products or services. However, the ecological crisis demands innovations, which are part of the solution, not of the problem. An eco-innovative approach emerges as a response to the need of changing current practices of 'business as usual'. Compared to traditional innovation, eco-innovation highlights environmental aspects, alongside economic aspects.

Fussler and James (1996) were possibly pioneers in the proposal of ecological innovation as a concept in Driving *Eco-Innovation*, a book that designates eco-innovations as "new products and processes, which provide customer and business value but significantly decrease environmental impact." Following the same idea, many authors have widened the scope of investigation, providing alternative definitions and posing new queries. Eco-innovation has a distinct characteristic compared to Schumpeterian terms[1], as it emphasises the reduction of environmental burdens (Prado & Issberner, 2016). In this sense, Kemp and Pearson (2008) proposed a definition for eco-innovation in an EU funded research project called "Measuring Eco-Innovation" (MEI)[2]. Based on the Oslo Manual (2005)[3], the authors describe eco-innovations as:

> "the production, assimilation or exploitation of a product, production process, service or management or business method that is new to the organization (developing or adopting it) and which results, throughout its life cycle, in reductions in environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives " (Kemp & Pearson, 2008, p. 7).

Besides environmental gains, Kemp and Pearson (2008) highlight that an environmental improvement achievement is not sufficient. A satisfactory outcome is the one that considers the whole product lifecycle and the supply chain in the analysis,

[1] Schumpeter, J. A. (1934, 1980). The theory of economic development. Oxford University Press: London.

[2] MEI is a project for DG Research of the European Commission, carried out in collaboration with Eurostat, the European Environment Agency (EEA) and the Joint Research Centre (JRC) of the European Commission. It offers a conceptual clarification of eco-innovation (developing a typology) and discusses possible indicators, leading to proposals for eco-innovation measurement.

[3] The Oslo Manual (OECD 2005) defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practice" (where implementation means realisation for use).

including all the stages from raw material extraction to the product final destination (Hellström, 2007). The life cycle analysis provides a wide perspective in production process, showing that a firm considered environmental friendly, due to a good performance at a certain point in the sequence, ends up showing a negligible result if the whole life cycle is considered in the analysis (Kemp & Pearson, 2008). Adding to environmental impacts reduction, some more recent definitions of eco-innovations have included the reduction of the use of natural resources and the discharge of unsafe substances throughout the whole life cycle (Eco-innovation Observatory, 2012).

These definitions help to expand the more usual focus on the end of life to the whole life cycle bringing up concepts such as sharing, leasing and remanufacturing to generate possibilities of new business models. Like other types of innovations though, eco-innovations may also happen when different materials are combined; along production processes; when new products are created or when new attributes are proposed to an existing product or service. They can also occur with the discovery of new raw materials, or when new markets or market niches are created as well as with the extension of the lifetime of a product (Motta et al., 2015). Despite the changes in definitions, it is important to bear in mind that the motivations for the development and adoption of these category of innovations may not be necessarily environmental. It is rather common that they are good for the business, having the environmental benefits as a kind of positive aftermath.

The Paris Agreement are expected to promote the development of this type of innovation. At least, that is what the sustainable development goals (SDG), especially Goal 12 - Ensure sustainable consumption and production patterns - promises to tackle. Additionally, digitisation, artificial intelligence, robotisation and so on, opened up some promising technological avenues for eco-innovation to progress.

4. Eco-innovation as a means to kick-start Circular Economy

Even in a positive scenario where political and economic forces support transitioning to circular economy, there remains the challenge of building a knowledge base, capable of promoting the necessary eco-innovations. What we have today is a knowledge base for innovation focused on an outmoded model, which means that we will need to create new knowledge and build bridges to connect already developed knowledge to the new requirements of the circular economy. The European Union has already made some progress towards the circular economy. New technologies, design concepts, services, and innovative forms of co-operation are being developed for this purpose. But too many gaps still remain to be bridged.

The transition to the circular economy depends on catalysing investments and innovations, giving rise to more eco-efficient modes of production. In fact, a fully-fledged circular economy will require radical and systemic eco-innovations to transform linear patterns of production and consumption. Such patterns have evolved over the past two centuries, creating regimes of overuse and waste of natural resources. Multiple approaches apply to reducing the use of resources in the economy, and increase resource efficiency and circularity, in the circular economy.

According to Eco-Innovation Observatory (2016), circular economy involves eco-innovations from two very different fields, which can be termed ‘hardware’ and

'software' of circular economy. In this model, technologies and technical infrastructures that would turn waste into resources again – hardware – and skills, expertise, and business models, that would turn these transformation processes into business opportunities – software (Eco-Innovation Observatory, 2014).

The 3 R's approach is most widely known: reduce, reuse, and recycle (Wu, Shi, Xia & Zhu, 2014; Yang, Zu & Xu, 2014). The 3 R's weakness lies on the fact that it focusses mainly on waste management; taking into account the fact that the waste has already been generated, new concepts have become necessary, to attain economic requirements. In this sense, the 6 R's approach is more adequate to meet the principles of circular economy. The 6 R's activities are: waste prevention (Reduce); sharing/leasing (Reuse); turn waste in new materials (Recycle), turn discharged products into new materials or products (Recover), turn materials recovered from the previous life-cycle in new materials (Redesign), turn already used products in new products restoring then to the original state (Remanufacture) (Jawahir & Bradley, 2016). Those activities are new for the industry, they have to be identified, deciphered, specified, designed, tested etc., until ready for running in a production process. All these steps are nothing else than a process of innovation. This is a challenge for the transition to a resource-efficient circular economy like the schumpeterian process of 'creative destruction'. To achieve both the 3 R's and the 6 R's, a major effort in eco-innovation will be paramount.

Regulatory and consumer pressures play a role in the transition to a circular economy. The transition involves changes in institutions, meaning, social, ethical, and environmental values, which do not come spontaneously. Those changes will have an impact on traditional institutions that support traditional business, but will also generate opportunities to be captured through innovations, been more precise, through eco-innovations. Those pressures have the power to trigger the process, persuading firms to change their way of producing, packaging, delivering products, and discarding waste. Appropriate policy instruments may contribute to the spread of innovation culture, helping stakeholders to meet the multiple objectives of circular economy, related to environmental, economic, societal/managerial, and topological (Winans, Kendal & Deng, 2016). Such factors reinforce the need of eco-innovation development and diffusion (Horbach, Rammer, & Rennings 2012; Kemp, 2008; Motta, 2013; Jaffe & Palmer, 1997).

The instruments to promote eco-innovations for the circular economy are in the beginning of its existence. If favourable environment opened up for circular economy, the measures adopted will be: the development of new practices based on sharing, reusing, repairing, as well as remanufacturing. In addition, at national level a number of measures could be taken, such as:

• Regulatory instruments, such as regulations on recycling, producer responsibilities, eco-design, mandatory targets, codes, standards, and certification for products; Economic instruments, including fiscal and financial incentives, direct funding, and public procurement;
• Research, development and deployment support measures, such as grants for R&D and piloting activities, R&D infrastructure, innovation vouchers, supporting innovation incubation, and R&D personnel;

• Information, education and networking support measures, for example, advising, training, offering direct support in activities to SMEs, customers, technology adopters, promotion of networking, providing information, and supporting public private partnerships, and
• Voluntary measures, such as performance labels and guarantees for products and services, or voluntary agreements and commitments.

Certainly the transition to a circular economy will not be easy. There is a myriad of obstacles intervening such as falling commodity prices, insufficient investment, lack of skills and expertise, limited acceptance of alternative models of consumption and business, and lack of political coherence. These have to be addressed in a comprehensive way by favourable framework conditions (e.g. embracing regulation, institutional settings, targets, instruments, curricula, infrastructures, networks, key actors, etc.).

5. Conclusions

This paper starts addressing the circular economy in order to contribute to the advancement and improvement of its theoretical approach. A brief literature review shows that innovation play a key role in the transition to circular economy. Our contribution in this paper is to reinforce the role of innovation, but emphasising its environmental aspect, which means highlighting the eco-innovations.

Circular economy brings a powerful logic to reshape the design of products, production processes, and disposal, in order to meet the requirements of reducing natural resources use, greenhouse gases emission, and environmental pollution. Mainly focusing in three goals: reduction, reuse and recycle, this approach has been influencing the innovation policy of many countries.

It is expected that this paper can provide sufficient elements for understanding the interrelations between eco-innovations and circular economy. It is also expected that future case studies could be developed to further contribute to this field of analysis, as well as motivate practical applications of eco-innovations in a circular economy model.

A final remark to this paper is that we do believe that eco-innovations are crucial to sustainability transition. But a lot more is necessary to reduce greenhouse gas emissions, particularly phasing out subsidies to energy production through fossil fuels and massive adoption of renewable energy sources. The transition will not come about in an automatic and natural way, but will require a better and widespread understanding of the risk of continuing on the same path of indefinite economic growth. Civil-society pressure is necessary for political and market action to pave the way from the contemporary growth society to a future flourishing society.

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Contact email: mottaw@gmail.com