

Circular economy: analysis of the implementation of practices in the Brazilian network

39

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Abstract

Purpose – In total, 19 practices of circular economy divided into three groups, internal environmental management, ecological design and investment recovery were studied in a local network composed of small companies and individual entrepreneurs related to common product and by-product flows. The paper aims to discuss these issues.

Design/methodology/approach – This research presents an applied nature, is characterized as exploratory and adopted the case study as a technical procedure using sources and methods of data collection. The primary data were collected through direct observation of the processes and semi-structured interviews with managers and owners.

Findings – The most widespread practices are related to product design. However, in most cases, the implementation was punctual and did not present continuous and corresponding actions, which highlights the embryonic contours of European Commission (EC) in the observed network. The practices from the management category were less observed, which reveals the environmental variable is not included in the strategic business planning.

Research limitations/implications – The research documents the application of CE practices in a local network and brings this current paradigm shift to the Brazilian context.

Practical implications – To overcome barriers to the implementation of EC practices, it is suggested to restructure commercial relations, to formulate public policies and to develop infrastructures that facilitate the materiality of flows and the market.

Social implications – The study highlights the need of public policies that promotes cross-sectoral cooperation in accordance with NSWP objectives.

Originality/value – Despite the focus on EC implemented practices this study offers a framework of the research routes on the main barriers and suggests actions to overcome the challenges in the transition from the economy to the circular model.

Keywords Barriers, Waste management, Case study, Circular economy (CE), Environmental management

Paper type Research paper



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1. Introduction

The patterns of production and consumption have put substantial pressure on the environment. This fact has created the risk that the absorption capacity of the planet will be compromised and the threat of ruptures in breaking ecological stability due to the accumulation of pollution. Global sustainability depends on the dissociation of the rates of economic growth and resource consumption, so that productivity can be achieved through technological, relational and institutional innovations (Fischer-Kowalski and Swilling, 2011).

Agenda 2030, an agreement signed by more than 190 countries, includes 17 sustainable development goals (SDG). Among these, SDG 12 proposes to assure sustainable production and consumption standards. Moreover, this agreement establishes several goals, such as sustainable management, efficient use of natural resources, mitigation of pollution and its impact, the implementation of practices that prevent the generation of waste, and the prioritization of reuse and recycling processes (UN General Assembly, 2015).

The role of the governments associated with Agenda 2030 is to elaborate public policies that involve the manufacturing and agriculture sectors of society in order to meet the goal of reducing the amount of waste generated. In addition, the role of companies encompasses committing to sustainability, adopting new perspectives, realigning their business models and acting interdependently (Cepal, 2016).

Cooperation among companies is established by relationships that integrate environmental actions between suppliers and consumers. Moreover, it is the task of research to highlight that these integrated environmental actions have economic and political relevance (Ioppolo *et al.*, 2014).

The literature presents a profusion of studies related to the topic of cooperation among companies, which is carried out mainly in developed countries. However, with regard to Brazilian companies, the transition to sustainable production requires methodologies and practices adapted to the local reality because of the lack of structure and training (Gomes *et al.*, 2013).

The CE proposes to reduce the environmental impact, and at the same time, promote economic growth through business development and new revenue streams (Kalmykova *et al.*, 2018). As a system that minimizes waste generation and emissions, and mitigates material and energy loops to preserve resources, CE can contribute to sustainability through conditional, beneficial or trade-off relationships (Geissdoerfer *et al.*, 2017). Like environmental sciences and sustainable development, CE is aimed at helping to resolve environmental issues (Sauvé *et al.*, 2016).

This study aimed to analyze the implementation of CE practices in a network of individual entrepreneurs and small companies that participates in flows of products and by-products in common.

In addition to this introduction, this paper includes five other sections. The theoretical foundations that underlie this study are presented in Section 2, while Section 3 describes the research in terms of its methodological procedures. Further, the results are reported and discussed in Section 4. Finally, the fifth section presents the final considerations, the contributions and limitations of the research and suggestions for future studies.

2. Literature review

2.1 *The roots of the CE*

As highlighted by Merli *et al.* (2017), CE is a concept that shares many common principles with others, including industrial ecology (IE). It emerged as connected IE, which is particularly related to the exchange of the by-products and waste that are mirrored in the natural cycles of material and energy (Gregson *et al.*, 2015). The IE concept is described as a multidisciplinary study of industrial and economic systems and their links to essential natural resources (Allenby, 2000).

In the biological sciences, the term symbiosis is used to describe a type of interspecific harmonic relation that brings benefits to living organisms (Odum and Barrett, 2011). Similarly, IE employs the term industrial symbiosis to describe the organizational interactions related to resource and waste recycling (Lifset and Graedel, 2002).

The use of the biological analogy by IE suggests that concepts such as recycling and load capability linked to the basic characteristic of an industrial ecosystem consist in the resilience, or in other words, the ability to interact with the environment and enable its regeneration (Ehrenfeld and Gertler, 1997). The key elements of IE are the biological analogy, system perspectives, technological modifications, cooperation, dematerialization, eco-efficiency and research and development (White, 1994). IE can be stratified by the extent of the interactions. The first aspect refers to the degree of dependence on natural ecosystems in relation to the resource supply, as well as the waste and emissions disposal channels, and the level of impairment of the load capability of the planet; moreover, it is divided into elementary, intermediate and self-sufficient models (Jelinski *et al.*, 1992; Lifset and Graedel, 2002).

There are at least two ways in which IE themes can be incorporated into a larger whole. One way is to view IE as operating partly at the firm or the unit process level (design for the environment, pollution prevention, eco-efficiency and “green” accounting), at the inter-firm (eco-industrial parks [industrial symbiosis], product life cycles and industrial sector initiatives), district or sector levels, and finally, at the regional, national or global levels (budgets and cycles, materials and energy flow studies and dematerialization and decarbonization). While the firm and unit processes are relevant, much of IE focuses on the inter-firm and inter-facility levels, because pollution prevention or related aims address many of the significant issues at the firm, facility or unit process levels (Lifset and Graedel, 2002).

Another way to link the elements together is to see them as reflecting the theoretical aspects of IE in many of the interdisciplinary aspects of the field (systemic analysis of resources and social and economic), while according Lifset and Graedel (2002), the more practical and applied aspects appear in ecodesign.

IE provides a beneficial and inclusive economy by focusing on minimizing resource consumption and waste disposal (Andersen, 2007). Like industrial symbiosis, urban symbiosis can also contribute to strengthening the CE by means of transforming physical resources into economic benefits (Su *et al.*, 2013; Wen and Meng, 2015).

As highlighted by MacArthur *et al.* (2015), circularity is deeply rooted in history, and CE correlates with several schools of thought. In the concept of cradle-to-cradle, CE seeks to avoid the final disposal of products and promote the recycling of materials, transforming them into inputs and raw materials (McDonough and Braungart, 2010).

Economic performance contributes to the CE through principles such as the manufacturing of durable products and focusing on maintenance services that allow the extension of the useful life of the products (Stahel, 2010). Moreover, regenerative design has influenced the CE in relation to the rational use of natural resources with the aim of avoiding their depletion and environmental degradation (Cole, 2012; Lyle, 1996).

For the CE, natural capitalism proposed the perspective that biotic and abiotic resources constitute the world’s inventories of natural assets (Hawken *et al.*, 2013); however, the blue economy suggests that energy sources should be regarded as a keystone of economic systems, which should be limited to the ecological conditions of the environment in which they are inserted (Pauli, 2010).

Biomimicry or biomimetics is recognized as a principle compatible with the CE because nature is taken as a model of design (Pomponi and Moncaster, 2017). For example, some lessons interpreted by Bhushan (2009) include the chemical energy conversion by plants, the energy production by aquatic animals, and reversible adhesion in dry and wet environments by insects, reptiles and amphibians.

The CE is a divergent concept in the literature stemming from several epistemological fields (Homrich *et al.*, 2018). Many other correlations could be established among the CE and the major environmental concepts that have emerged in the past, including the green and bio economies. As D'Amato *et al.* (2017) showed, those concepts were postulated by a pool of social players such as academics, NGOs, industries and policy makers and their definitions overlap.

Kirchherr *et al.* (2017) identified 114 different definitions for CE, highlighting the lack of consensus. The CE refers in practical terms to reuse at three levels: the product level, such as repair or refurbish; the component level, such as, for example, remanufacturing; and the material level, which is regarded as recycling (Zink and Geyer, 2017). The CE proposes the arrangement of a system in which the efficiency of the use of resources is increased. In addition to being reduced, waste is used as a source of material and inputs for companies organized in networks that is unlikely in the linear economic standard of the consumption of resources, production and disposal (Geng *et al.*, 2016; Koci *et al.*, 2016). Despite the originality of the concept, proponents emphasize that the most significant contribution of the CE is the combination of different strategies from past attempts in a new framework (Bocken, Olivetti, Cullen, Potting, and Lifset, 2017).

2.2 Drivers and barriers to CE

The evolution of the CE concept has been shaped by different cultural, social and political aspects (Yu *et al.*, 2015). For instance, while China adopted the CE as a top-down strategy of development and as a control instrument, the European Union, North America and Japan have approached this concept as a bottom-up policy (Winans *et al.*, 2017).

At the end of the 1990s, the CE was inserted in Chinese public initiatives by means of policies to support research, articulations between stakeholders and the implementation of eco-parks, and was focused mainly on waste recycling (Yuan *et al.*, 2006). The second phase of expansion, which was based on the lessons learned from the problems of technical unfeasibility and economic difficulties, redirected the focus of the CE to the industrial structure (Geng *et al.*, 2016; Yuan *et al.*, 2006).

Regarding the early application of the CE, China was the leading country in terms of publications, while in publications from Europe, the usage of the term CE became more common after the European Commission (EC) addressed the issue of waste in 2014 (Türkeli *et al.*, 2018).

The EU started the transition with the publication of the Circular Economy Action Plan in 2015, which preceded the environmental directives EC 2005, EC 2011a, EC 2011b and EC 2011c. The EC framework was based on eight building blocks: industrial symbiosis, material resource efficiency, product life-cycle extension, biological products, energy efficiency and renewable energy, the performance economy, the sharing economy and finally, the platform economy (Taranic *et al.*, 2016).

Despite divergences in governance paradigms and context, China and Europe are the forerunners in the CE; the evolution of the concept in each of the regions can provide lessons for the other. According McDowall *et al.* (2017), China encourages and coordinates the transversal development of the CE through zones, regions and cities, where leading firms and institutions are the focus of different administration programs, such as experimentation and the coordination of management; further, the Chinese approach to the CE includes land-use planning.

On the other hand, Europe has provided a model of product labeling requirements that has been followed by a substantial number of countries, as has its product standards and experiences with the eco-design process and the promotion of business model innovation. In addition, McDowall *et al.* (2017) highlighted the possibility for synergy between the two areas.

In Brazil, the CE is supported by the National Solid Waste Policy (NSWP) (Brazil, 2010), which institutes a shared responsibility policy for the product life cycle and establishes reverse logistics as an instrument of economic and social development through an environmentally friendly waste disposal process (Azevedo, 2015; Demajorovich and Migliano, 2013). Although it is a beginning, the approach to waste management represents a small part of the potential of the CE, which incorporates effective proposals for resource management, such as regenerative design (Lyle, 1996), economic performance (Stahel, 2010) and a cradle-to-grave approach (Braungart and McDonough, 2009), among others.

In addition to environmental reasons such as resource scarcity stemming from unsustainable patterns of production and consumption, the economic benefits from new markets is a relevant driver for the transition to the CE (MacArthur *et al.*, 2015). The literature proposes a large number of new possibilities for business models, for example, the integration of key stakeholders and data in the development of CE strategies (Jabbour *et al.*, 2017). Other strategies include remanufacturing and sharing models (Bocken, Ritala, and Huotari, 2017).

In the literature, the formulation and application of the CE concept is considered fragile because of the lack of methodological cohesion in the criteria for measuring results (Bjørn and Hauschild, 2013). The proposed solutions to this problem include the adoption of effective indicators of waste reduction (Veleva *et al.*, 2017), life cycle assessment (LCA) methods for the design and measurement of performance (Scheepens *et al.*, 2016), and streamlined life cycle analysis, which is a quicker and cheaper approach than LCA (Gnoni *et al.*, 2018). Furthermore, the focus on the production and services system aligned with environmental preservation is not related to the social dimension or to the results that can be expected in terms of balance (Murray *et al.*, 2015).

The CE's focus on waste management also generates disapproval from part of the scientific community because of limiting conditions such as the unfeasibility of the reuse, recycling or recovery of certain types of waste, either for technical or economic reasons. The quality and quantity of recovered materials is a critical aspect for the stock supply of a growing economy, as well the energy required for transformation, and because primary resource extraction is necessary for all economies (Cullen, 2017; Lèbre *et al.*, 2017; Murray *et al.*, 2015).

As a social phenomenon, the CE finds limitations in the biological, chemical or technical concepts for matching materials appropriately, mainly those regarding the management of hazardous or potentially hazardous substances embedded in material cycles (Bocken, Olivetti, Cullen, Potting, and Lifset, 2017). An overview of the CE concept by Korhonen *et al.* (2018) highlighted that the complexity of material will be increased with new usages and combinations, because the environmental impact assessments of biofuels, biomaterials and other eco-efficiency initiatives remain incomplete due to unsolved methodological issues and other limitations.

The CE concept has gained momentum over time among private and public institutions; however, there are several challenges the concept must overcome to move society toward sustainability.

3. Research design

This research presents an applied nature and is characterized as exploratory, because it intends to approach the theme, as well as to solve specific problems, by performing an intensive analysis of an individual unit, such as a person or community, stressing developmental factors in relation to the environment (Prodanov and Freitas, 2009). In relation to the operationalization of the research, the significance of the condition of the contexts in which the players are inserted favored the choice of the case study as a technical procedure (Yin, 2015).

Among 32 pallet manufacturers that were contacted by phone, 26 agreed to respond to the questionnaire regarding the implementation of the CE practices presented in Table I.

Table I.
Circular economy (CE)
practices

Constructs	Circular economy (CE) practices
Internal environmental management	P1 Environmental commitment from senior managers
	P2 Support for environmental management from mid-level managers
	P3 Cross-functional cooperation for environmental improvement
	P4 Special training for workers on environmental issues
	P5 Total quality environmental management
	P6 Environmental auditing programs such as ISO 14000 certification
	P7 Eco-labeling of products
	P8 Existence of pollution prevention programs such as cleaner production
	P9 The internal performance evaluation system incorporates environmental factors
	P10 Generation of environmental reports for internal evaluation
Ecodesign	P11 Design of products for reducing consumption of material/energy
	P12 Design of products for reuse, recycling, recovery of material, component parts
	P13 Design of products to avoid or reduce use of hazardous products
	P14 Design of processes for minimization of waste
Investment recovery	P15 Investment recovery (sale) of excess inventories/materials
	P16 Sale of scrap and used materials
	P17 Sale of excess equipment
	P18 Collect and recycle end-of-life products and materials
	P19 Establish a recycling system for used and defective products

Source: Zhu *et al.* (2010)

The scientific production regarding the CE has increased significantly in recent years. A search in the Scopus database using the term “circular economy” in the article titles, limited to 2016 and 2017, produced 367 papers. Nevertheless, this research followed the premises that were validated by Zhu *et al.* (2010) in a study conducted in the Chinese industrial sector with more than 300 companies.

Although the study that supports this research was developed at the early stage of the CE in China, its framework is supported by recent empirical research, such as a case study developed by Manninen *et al.* (2018) among share and regenerate firms in Finland, as well as the review conducted by Petit-Boix and Leipold (2018) about the implementation of circular economy practices at the city level. Similarly, in Brazil, Sousa-Zomer *et al.* (2018) adopted the same nature of practices in a case study to provide evidence of the linkage between the CE and cleaner production.

From 14 valid questionnaires that were answered, this study identified that the number of practices implemented ranged from two to ten. In addition, the majority of companies (64 percent) adopted up to five CE practices in their processes. The companies that identified the highest number of practices were contacted again; however, only the firm identified as Alpha Company agreed to participate in a qualitative survey.

Alpha Company and other firms are identified, and all of them became players in the network shown in Table II. They are located in Ibiúna City, which has an economy mainly based on agricultural production and supplies the metropolitan region of São Paulo with several horticultural products.

Alpha Company belongs to the mechanically processed wood products sector. This company manufactures pallets from lumber. Besides the product, the outputs of the process are three by-products: residues resulting from the processing of wood logs, wood shavings (by-product 1) and sawdust (by-product 2), differentiated by the granulometry, and the secondhand clapboard sidings (by-product 3) in the assembly phase of the pallets.

These by-products are absorbed as inputs in other processes and circulated among various supply chains. Figure 1 describes the relationship among the players, focusing on the flows and transformations of the by-products of Alpha Company.

Table II.
Mapping of network players

Players	Activities	Process
Alpha Company	Manufacturing of pallets	Wood processing: sawing and assembling
Beta Company	Manufacturing of briquettes	Pressing of wood waste
Gama Company	Breeding and slaughter of poultry	Cutting farms
Entrepreneur A	Recycling	Recycling of materials
Entrepreneur B	Transportation	Transportation
Farmer 1	Agriculture	Horticulture
Farmer 2	Agriculture	Organic horticulture
Retailer A	Food retailing	Prepare meals
Retailer B	Food retailing	Prepare meals

Source: Research data

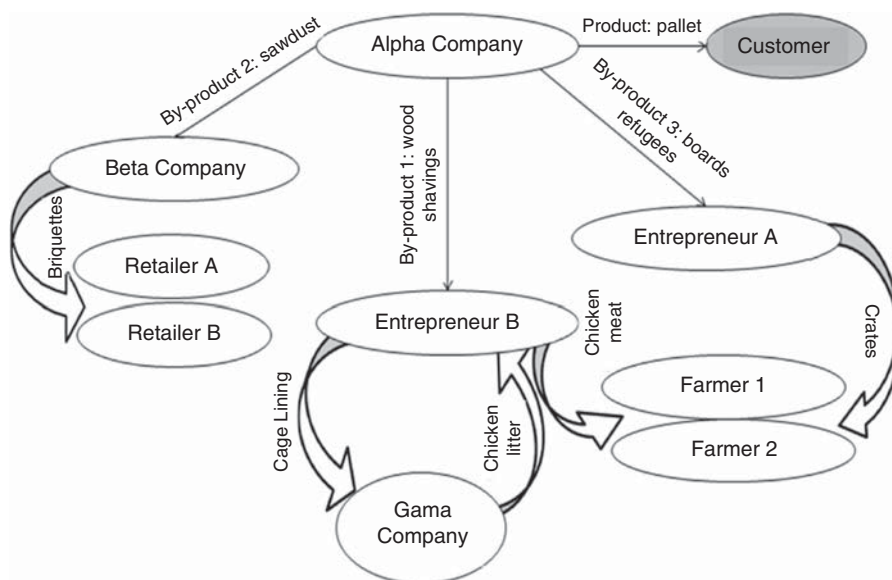


Figure 1.
Mapping of the flow and transformation of products and by-products among chains

Source: Research data

3.1 By-product 1 – wood shavings

According to Brandt *et al.* (2002), each 1 m³ of dry and classified wood sawn consumes 2.62 m³ of logs with bark. The chips resulting from the initial processes, such as debarking, unfolding and planning, are known as wood shavings. After they are driven by a treadmill out of the productive area and stored outdoors, the wood shavings are acquired by Entrepreneur B and resold to Gama Company for cage lining. After 49 days, when the breeding cycle ends, and the poultry are slaughtered, the shavings and the wastes they absorbed, now called chicken litter, are taken out by Entrepreneur B and resold to Farmers 1 and 2.

3.2 By-product 2 – sawdust

The waste, in the form of a powder, is collected by mechanical mats in the vertical, horizontal and refill sawing stages. The sawdust is stored in a protected place and sold to

Beta Company, which presses it under high pressure to obtain the briquettes. These cylindrical blocks of high calorific value are sold to Retailers A and B for the maintenance of ovens and wood stoves.

3.3 *By-product 3 – secondhand clapboard siding*

In the assembly phase, slats that have defects are segregated because they cannot be used in the manufacturing of pallets. This material is purchased by Entrepreneur A and transformed into household goods such as boxes that are sold to Farmers 1 and 2 for the packaging of hardwood and beekeeping.

Alpha Company, Gama Company and Retailer B are classified as small-sized companies according to the Brazilian Service for Supporting Micro and Small Enterprises (SEBRAE, 2016), and Beta Company and Retailer A are micro-sized enterprises. Entrepreneurs A and B are self-employed, while Farmers A and B operate under the cooperative regime, respectively, registered to family agriculture and organic agriculture programs. In a comparison of this framework to guidelines such as ReSOLVE proposed by the Ellen MacArthur Foundation, it is possible to identify two of six business model strategies as follows: the regeneration strategy corresponds to the flows of Alpha's by-products among the other players; and the loop with the restoration of the organic value of the chicken litter.

A cross-sectional perspective was adopted to portray the specific period from August to December 2017. The collection of the data, which utilized multiple sources and varied methods, allowed the mapping of the process and the by-product flow, as well as the identification of the network of players involved, as was presented in the previous section.

The primary data were collected through direct observation of the processes and semi-structured interviews with managers and owners. Secondary data were obtained by consulting various records, such as forestry origin documents, operating license waiver certificates, material and input purchase requisitions, material entry and exit reports, environmental labels, procedures, and safety information sheets of chemicals, among others.

Only the CE practices evidenced by three different sources, as suggested by the methodological triangulation described above, were considered implemented as presented. They are discussed in the next section.

4. Analysis and discussion of results

The industrial system is considered the producer of both products and waste. With this approach, the limits of a company are extended to the environment, requiring that products and waste should be developed and discussed among different companies (Zaneti *et al.*, 2009). The players are integrated in a network in which individual entities become engaged in transactions for resource exchanges of materials, energy or by-products at the inter-firm or same level as described by Ghisellini *et al.* (2016).

In terms of special conditions, although the players are not placed within strict boundaries like a park, they are geographically close enough to promote circularity and to take advantage of the exchange of material and energy flows. According Chertow (2012), this type of symbiosis occurs among regional firms.

The participation of all the players constructs the network with originality and exclusivity. As argued by Domenech and Davies (2011), the network morphology is determined by the density and connectivity of the players.

Figure 2 shows the implementation of CE practices quantitatively. Although the intentionality in the network formation was observed, and although the players emphasized the importance of the circularity of materials, the findings showed that the players implemented less than 50 percent of the actions, so that the minimum verified was two practices and the maximum was ten.

In terms of quantity, Alpha Company and Farmer 2 presented the highest results, with ten practices each, while Entrepreneur B presented only two. A single practice was common to all players; P12 is related to the design of products for the reuse, recycling and recovery of materials of component parts.

The process of producing organic vegetables is aligned with environmental protection from the preparation of the land to the delivery of the product; as Farmer 2 reported:

[...] we do not use pesticides and chemical fertilizers. For instance, the planting accompanies the unevenness of the land to avoid erosion, the irrigation method is economical and supplied with rainwater; moreover, we generate solar energy, and the transport of the products is associated with the other cooperatives.

Patterns of the comprehensive utilization of water and energy, as well the principles of ecology and sustainability are predicted for circularity in agriculture (Xuan *et al.*, 2011). Farmer 2 emphasized that a hindrance to the full conversion to the CE is the low investment in technology and infrastructure, and the need for technology transfer was pointed out by Xi (2011) in a study about the models of the CE in agriculture.

The manager of Alpha Company highlighted the strategies that produce sustainability:

Because of the quantities generated, we prefer to market the by-products rather than process them. This fact is relevant for middlemen because it fosters the economy. For us, it also recovers investment and reduces losses, allows us to optimize the process and keep focused on the product, which guarantees reaching more customers.

The lack of awareness of society regarding the consequences of current development standards is one of the obstacles to sustainability (Jacobi, 2003; Jacobi and Bensen, 2011). The pressure of customers is a driver for CE transition (Moktadir *et al.*, 2018). According to Entrepreneur B, CE practices are not applicable to all markets:

I saw the opportunity to sell a service instead of charging only for the freight. In addition, I started to buy the sawmill and sell it to the farm with the guarantee of withdrawal. For the customer, the service is convenient and the price advantageous. For me, it is an investment because I make a profit when I sell the chicken litter to the farmer. Nonetheless, this is not my main activity. My main income comes from being a carrier of cargoes, and unfortunately, in this situation, there is not much to do for the environment.

Four out of the 19 CE practices were not evidenced: P5 – quality and environmental management system integration; P6 – environmental auditing programs such as ISO 14000 certification; P9 – the internal performance evaluation system incorporated into environmental factors; and P10 – the creation of environmental reports for internal evaluation.

This deficiency was found in several small companies studied by Mello *et al.* (2015). They pointed out that environmental issues are often addressed through non-systematized

Players	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	Total	
Alpha Company	■	■	■	■			■	■			■	■	■	■	■	■			■		10
Beta Company	■	■						■			■	■	■	■						■	3
Gama Company	■	■	■	■				■			■	■	■	■	■					■	4
Entrepreneur A	■	■						■			■	■	■	■					■	■	5
Entrepreneur B	■	■						■			■	■	■	■						■	2
Farmer 1	■	■	■	■			■	■			■	■	■	■	■	■					8
Farmer 2	■	■	■	■			■	■			■	■	■	■	■	■	■	■			10
Retailer A	■	■					■	■			■	■	■	■							3
Retailer B	■	■					■	■			■	■	■	■		■					4

Legend

- Practice verified by all sources of collection
- Practice verified through up to two data sources. However, the implementation cannot be evidenced
- Denote that the practice was not verified through any collection source

Source: Research data

Figure 2.
Evidence of implementation of CE Practices

practices, which are focused on complying with legislation and waste recycling policies. These findings are consistent with the study of Degenhart *et al.* (2016), which identified the reactivity or animosity of companies in relation to the disclosure of their environmental information, which is not required by law.

The managers who perceive environmental issues as a business opportunity tend to integrate them into the company's strategic planning, implement new technologies, institute training programs, as well as establish organizational incentive policies (Dubey *et al.*, 2018; Muduli *et al.*, 2013).

The implementation of practice P1 – commitment of environmental management from senior managers was recorded only among the players who had the greatest number of practices implemented: Entrepreneur A, with seven practices implemented; Farmer 1, with 10 practices evidenced, as well as Alpha Company and Farmer 2, which implemented 12 CE practices, a number equivalent to more than 60 percent of the researched constructs.

On the other hand, the lack of commitment of the top management is related to the absence of knowledge and control over the environmental aspects (Govindan *et al.*, 2014; Oelze, 2017). For instance, during the follow-up to the removal process of the chicken litter, it was observed that the vehicle had oil leaks and emitted excessive black smoke. Additionally, evidence of periodic maintenance could not be verified, and when asked about this, Entrepreneur B was not knowledgeable about the consequences of these sources of pollution for the environment or the importance of maintaining good conditions for the conservation of the vehicle for economic safety reasons.

Most of the players do not have a hierarchical structure that supports middle management, which is why practice P2 – support for environmental management from mid-level managers was verified only in the three companies constituted and classified as small.

Alpha Company incorporates the environmental aspects in its training on health and safety at work (P4). Rural cooperatives act as centers of knowledge diffusion and produce empowerment in ecologically based agriculture (Almeida and Abreu, 2009). According to Farmer 1, the techniques learned improved production and environmental quality: "We usually do the training in the cooperative and then teach the rest of the family and employees. The technician also visits the property, accompanies the project and clarifies the doubts."

Organic agriculture requires adequate procedures and technologies (Souza *et al.*, 2015). Farmer 2 reported that the change from the traditional to organic farming was guided by the cooperative: "Without the use of pesticides and chemical fertilizers, our products are healthier, the land is more fertile, the cultivation has become cheaper, and we have a relevant market." These aspects correspond with the study of environmentally friendly practices for agriculture districts in China (Toop *et al.*, 2017).

The fact that practice P3 – cross-functional cooperation for environmental improvements was evidenced in the same players that implemented P4 (special training for workers on environmental issues) corroborates the findings in the literature that the ability of employees to contribute to environmental activities can be increased through training (Alayón *et al.*, 2017).

Environmental labeling is not widely used among the players in the network; therefore, the implementation of practice P7 was evidenced in only two of them. The statements of both converge to emphasize the importance of family and organic agriculture labels for sustainable production. According to Farmer 2:

[...] the consumer can not differentiate the vegetables produced in an organic way from those produced by the conventional system; therefore, this consumer needs some identification to trust that the product is free from pesticides, and the producer also needs to defend his market.

Thus, Moura (2013) pointed out that environmental labeling meets these economic and communication needs, as it differentiates the product from its competitors. Further, Lombardi *et al.* (2017) found that exposure to information about environmental practices can positively change consumer behavior.

Cleaner production practices constitute a milestone in the transition to a circular business model (Sousa-Zomer *et al.*, 2018). Pollution prevention actions (P8) were evidenced among rural producers, such as the use of biodiesel as fuel for generators. Other pollution control and treatment interventions, known as “end-of-pipe” measures (Glavič and Lukman, 2007), such as systems for the treatment of domestic effluents by septic tanks and bio filters, were verified for Farmer 2; for Alpha Company, containment basins for chemical product deposits were verified.

CE practices related to the planning and design phase (P11 to P14) stand out as the most frequently implemented. In order to reduce the consumption of resources and materials (P11), the most commonly performed actions were energy acquisition by contracted demand, the replacement of machine parts, and the use of economical lamps by the Alpha and Gama companies. The rural producers used solar energy, rainwater and irrigation by drip and micro sprinkler techniques.

It was observed that the P12 practice, common to all players in this network, interconnects them in the flow of the reuse, recycling and/or recovery of Alpha Company’s by-products. Moreover, it is aligned with the NSWP, regulated by the provisions of Federal Law No. 12,305/2010, which recommends the final disposal of waste in landfills only when other treatment alternatives are unavailable (Brazil, 2010). The CE does not find consistent support in the Brazilian legal system, because the programs foreseen by the NSWP have not yet been effectively implemented, and there are no official EC indicators, which constitutes a barrier to the EC, as identified by Galvão *et al.* (2018).

For Gama Company, it was not possible to confirm its declaration regarding the commitment to eliminating or reducing the use of dangerous products (P13). It was observed that the packaging and residues of various chemical products such as medicines for birds and sanitizing products were discarded along with the common waste, and their final destination was the municipal sanitary landfill. The environmental contamination by drugs is associated with potential impacts on human and animal health, for instance, the risk of the development of resistant bacteria and other unknown adverse effects (Eickhoff *et al.*, 2009).

The processes of Alpha Company and Entrepreneur B were the leanest and the most highly waste recyclable, and therefore, the most aligned with practice P14.

The practices aimed at the recovery of investment (P15 and P17) were evidenced only in Farmer 2, who mentioned having sales and exchange relationships facilitated by the cooperative. The other players declared that they work with suitable materials and equipment for their production. As stated by Alpha Company’s manager, “the production needs to match to the incoming material; therefore, we cannot stock either the raw material or the product.” As pointed out by the owner of Beta Company, there is no excess of equipment.

The implementation of practice P16 – sale of scrap and used materials was validated in Alpha Company through the flow of its by-products and was also evidenced for the retailers that sell aluminum and paper waste.

The practices P18 and P19 were evidenced only in Entrepreneur B, which in addition to recycling the waste of Alpha Company uses various materials such as scrap metal, tires, electrical appliances and electronics in the manufacture of decorations and utilities.

The CE concept includes the prevention of toxic materials and waste recycling, protecting the environment from their use as non-toxic elements (MacArthur *et al.*, 2015). The importance of adopting technical criteria for the use of chicken litter as a biofertilizer is stressed in order to avoid environmental degradation (Corrêa and Miele, 2011). The studies have pointed to the persistence of antibiotics and pathogens in chicken litter after composting (Hahn *et al.*, 2012) and the contamination of crops by lead (Machado *et al.*, 2008) and copper (Ribeiro *et al.*, 2007). There was no evidence that Farmers 1 or 2 had any mechanism to monitor the risk of contamination.

Although the players are aware of the relevance of their environmental contributions, the network was formed intuitively and did not receive any institutional support or coordination.

There were fewer observations of practices in the management category, which confirms the tendency pointed out in Giunipero *et al.* (2012) study for the environmental variable not to be included in strategic business planning.

As pointed out by Abreu and Ceglia (2018), the CE business model requires institutional capacities to be strengthened through market instruments, public and private partnership policies and legislation.

Although it was beyond the scope of this paper, the study of CE practices led to the identification of barriers to its implementation. There is a gap between the expansion of environmental management and the application of a beneficial economy to the environment (Fuks, 2012). Consensus was found among the players interviewed that CE practices compete with other priorities, and for financial reasons, are often overlooked. The same problem was found for the small companies studied in the Basque by Ormazabal *et al.* (2016). Clients' lack of interest in the environmental aspects regarding the product or service was a recurring justification for the non-implementation of CE practices.

Entrepreneur A recognized that there would have been more opportunities for production and growth if companies did not keep their processes stagnant and were open to integration: "Most industries do not have any interest in unconventional materials and processes." The resistance to change and the shortsightedness identified among the stakeholders were considered to be the main causes of failures in the agricultural CE in Finland (Kuokkanen *et al.*, 2016).

Gama Company believes that CE practices would be more easily implemented if organizations shared the knowledge they gained: "Even companies operating in different markets behave as competitors and keep their experiences confidential. As there is not any possibility of exchange, adherence to CE practices requires time and investment in training or consulting, which makes it an unfeasible change." Common concerns such as climate change, resource scarcity and other environmental issues require deep discussions and shared experiences (Korolev *et al.*, 2018).

Other points cited by the interviewees were the lack of tax incentives to reuse materials and increase the shelf life of products, as well as the price of some recycled raw materials, which are generally uncompetitive or even more costly than virgin raw materials. The use of incentive taxes has been highly recognized by authors as an instrument to foster the implementation of environmental policies aimed at achieving several objectives, from energy saving (Yi, 2014) to innovation (Liao, 2018).

The barriers identified by the network players are consistent with the literature; however, there are some classification differences, such as those found in the study of CE barriers by Galvão *et al.* (2018). A framework was developed based on the nature of the CE practices to be implemented in order to address the barriers frequently encountered, and actions were suggested to overcome the challenges, as shown in Table III.

The organizations must overcome internal obstacles to establish a cooperative network for the CE. The CE proposes a new configuration of materiality for which profound transformations are needed, not only in the productive processes but also in their foundations regarding the essential and non-essential demands that shape consumer patterns (Lieder and Rashid, 2016; Sauvé *et al.*, 2016).

Relevant measures to improve internal environmental management have been suggested, such as the continuous evaluation of environmental performance metrics, risk management, the alignment of policy, mission, vision and values with corporate environmental responsibility, the creation of a common platform of knowledge and information, investments in the ongoing training of employees and the dissemination of knowledge to stakeholders (Geng *et al.*, 2016; Mudgal *et al.*, 2010).

Furthermore, institutionalized models such as the creation of funds and credit lines for the execution of CE projects and the development of new markets for alternative materials,

Barriers identified		Suggested actions to overcome challenges		Authors	
Circular economy (CE) practices	Authors	Nature	Description	Authors	Authors
Internal environmental management	Manninen <i>et al.</i> (2018), Potting <i>et al.</i> (2017), Zhu <i>et al.</i> (2011, 2010)	Cultural	Risk aversion; Lack of support and motivation	Kirchherr <i>et al.</i> (2018), Liu and Bai (2014), Rzos <i>et al.</i> (2015), Su <i>et al.</i> (2013), Su <i>et al.</i> (2013)	MacArthur <i>et al.</i> (2015), Geng <i>et al.</i> (2016), Hopkinson <i>et al.</i> (2018), Urbinati <i>et al.</i> (2017)
		Contextual	Competition and uncertainty in the market; Lack of commitment of the consumer and other network players		
Ecodesign		Structural	Hierarchy and bureaucracy inhibit innovation Lack of learning mechanisms Lack of economic incentives Lack of human resources		
		Cultural	Resistance to innovation		Preston, 2012, Sauvé, Bernard, and Sloan (2016); Merli, Preziosi, and Acampora (2017) Ribeiro and Krughianskas (2014)
					International collaboration for the reuse, recovery and recycling of waste and by-products Fiscal incentive policies for the reuse of materials Standardization of average energy consumption and

(continued)

Table III.
Framework for research to implement CE practices

Circular economy (CE) practices		Barriers identified			Suggested actions to overcome challenges	Authors
	Nature	Description	Authors			
Investment recovery	Contextual	Lack of favorable regulations		minimum standards of performance of materials and products		Gregson, Crang, Fuller, and Holmes (2015)
	Structural	Competitor priorities; Lack of economic incentives				
	Cultural	Competition among the departments of a company				
	Contextual	Lack of integration with network players				
	Structural	Protected technologies; Lack of control and waste of materials and inputs				

Source: Research data

as well as the reformulation of waste collection and disposal rates, tend to encourage investment between companies and private partnerships (Ribeiro and Kruglianskas, 2014) as pointed out by Fischer and Pascucci (2017) in their study addressing institutional incentives for the transition to a CE.

In order for CE results to exceed waste exchange, a focus on product design and development is recommended. The use of integrated tools such as LCA, mass balance and dematerialization can propel organizations to a productive stage that challenges the traditional models of production, and consequently, of consumption (Preston, 2012; Sauvé *et al.*, 2016).

There should be no clash between economics and ecology in the constantly changing environment in which firms are embedded (Porter and Vander Linde, 1995). There are factors that may contribute to the recovery of investments; we highlight the systematization and diffusion of information aimed at increasing the bargaining power of companies, for instance, databases with projections of numbers and types of waste, technology sharing and collaborative product development (Gregson *et al.*, 2015).

The CE is based mainly on the Chinese and EU experiences. They have relevant differences from the Brazilian political and economic scenario, which lacks the legal framework to achieve the appropriate development of the CE. Another hurdle is related to the lack of economic instruments for and the participation of society in the rational use of natural resources. Those particularities require that caution be used in finding direct equivalence between efforts and policies (Mathews and Tan, 2016).

Therefore, the network of players studied has particular characteristics and faces several restrictions that may affect the timely implementation of CE practices, such as the decrease in the production of pallets due to the deceleration of the Brazilian economy since 2015 as a result of the economic crisis (Rossi and Mello, 2017), as well as the exhaustion of organic production due to its high price in relation to conventional agricultural products (Silva *et al.*, 2005).

The case study format was the second most used procedure among 500 published papers about the CE indexed at the Web of Science and Scopus databases up to April 2017. According to Merli *et al.* (2017), these studies aimed at applying the CE in specific contexts or comparing its geographical differences. Further, as pointed out by Petit-Boix and Leipold (2018), cities' initiatives to implement the CE are commonly reported in non-academic journals, and because of the absence of peer-reviews, these data sources are frequently avoided.

5. Final considerations

The CE is a topic that has evolved rapidly as a possibility to reconcile environmental preservation and economic growth. The joint efforts of academia, NGOs, public decision makers and stakeholders should be focused on the implementation of strategies and overcoming challenges.

The bibliometric study of the CE in the Web of Science, Scopus and Google Scholar data sources developed by Türkeli *et al.* (2018) noted that like India and some European countries, Brazil has produced many citations, but few effective contributions to the CE literature. Along with studies such as the one developed by Oliveira *et al.* (2018), this research aimed to document the application of CE practices in a local network and bring this current paradigm shift into the Brazilian context.

Despite the fact that this paper focused on the execution of CE practices, the findings allowed the mapping of research routes to address the main barriers and to suggest actions to overcome the challenges, i.e. the restructuring of business relations, the elaboration of public policies and the development of infrastructures that facilitate the materiality flows and the market.

In addition to this theoretical contribution, the study provides practical insights for managers and entrepreneurs with the purpose of implementing the CE business model, as well as highlights the need for public policies that promote cross-sectoral cooperation in accordance with the NSWP's objectives.

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