



Circular Business Model Innovation and Its Relationship With Business Performance in Brazilian Industrial Chemical Companies

Francies Diego Motke^{1*}, Clandia Maffini Gomes¹, Jordana Marques Kneipp¹, Ana Paula Perlin¹, Luana Inês Damke¹ and Tatiane Balbinot Lamberti²

¹ Postgraduate Program in Business Administration, Federal University of Santa Maria, Santa Maria, Brazil, ² Graduate in Production Engineering, Federal University of Santa Maria, Santa Maria, Brazil

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*Correspondence:

Francies Diego Motke
fdmotke@gmail.com

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This study aimed to analyze the relationship between circular business model innovation and business performance in Brazilian industrial chemical companies. This is a quantitative study carried out through a survey with Brazilian industrial companies. Based on a homogeneity analysis (Homals), the results showed that the high degree of innovation in business models from the adoption of circular economy (CE) strategies in the analyzed companies confirms that a significant change leads to superior performance, especially in market, production, economic and financial, and social.

Keywords: circular economy, innovation, business model, chemical industry, business performance

INTRODUCTION

Although products are becoming more resource-efficient, increasing consumption levels and the linear nature of the economic system have notably increased resource use and waste, consequently leading to environmental degradation. The negative effects of dominant production models based on collecting, manufacturing, and using resources and goods threaten natural ecosystems and affect human health and well-being (Braungart et al., 2007; Stahel, 2016). Hence, in the search for alternatives to unsustainable resource use, industrial ecology has provided the basis for a circular economy (EC).

The CE envisions achieving a more effective and resource-efficient economic system by intentionally narrowing, slowing, and closing material and energy flows (Ellen Macarthur Foundation, 2015; Bocken et al., 2016). In this sense, companies engaged in this circular process should extend their concerns with economic-financial viability to strategies aimed at perpetuating the business and concern with society and the environment; therefore, organizations must adopt a business model that meets circularity precepts (i.e., they must consider adopting a business model that meets the CE).

The adoption of practices that lead to CE requires significant changes and investments to modify existing linear models in planning, production, and management of the supply chain (Fusion, 2014). This also implies a shift from material-intensive business models to service-based business models and the improvement of more collaborative partnerships (Fonseca et al., 2018).

For this, companies have to be aware of this new paradigm to attract new business opportunities. According to Aboulamer (2018), the shift in consumer attitudes toward a product-to-service paradigm provides companies an excellent opportunity to gain financial resources and move from a linear to a circular business model. Circular business models often capitalize on new revenue

sources from the product or material cycle, such as selling company waste or byproducts or reducing procurement costs for raw materials when replaced by secondary materials (Moreno et al., 2016). Companies can also capitalize on post-consumer markets and capturing value by repairing and reselling products or reusing and upgrading them. In fact, moving toward the CE may contribute to superior business performance, that is, better performance compared to companies in the same sector, and some studies expect the CE to have a positive impact on both the environment and economic growth in the coming years (Ellen Macarthur Foundation, 2013; Lehmann et al., 2014; European Environment Agency, 2016; Geissdoerfer et al., 2017; Masi et al., 2017).

Given this context, the chemical industry plays a vital role as a technological innovation agent for several upstream and downstream production chains and, therefore, has great potential to enable CE guidelines (Tavares, 2018). In addition, the chemical industry occupies the third position in the ranking of contribution to the transformation industry, being responsible for the control of various types of inputs (ABIQUIM, 2018). With this, the scope of the chemical industry through the consumption of chemical products in several sectors of the economy becomes evident. Therefore, upon realizing the benefits not only for the environment, but also for economic and social reasons, the adoption of CE's precepts in their business could impact several business sectors.

For this reason, the new business models adopted by industrial companies in the chemical sector can promote the closure of material cycles in order to achieve circularity and, thus, promote superior business performance. Therefore, this study aims to analyze the relationship between circular business model innovation and business performance in Brazilian industrial chemical companies.

CIRCULAR BUSINESS MODEL

The literature on the business model has significantly grown since the 1990s; the business model can be understood as a representation of how the company does business (i.e., how it creates and delivers value to the customer to generate revenue and achieve a sustainable competitive position) (Taran et al., 2015). Osterwalder et al. (2005) described the business model as a conceptual tool that helps understand how the company operates and can be used to analyze, compare, and evaluate performance, management, communication, and innovation in the business environment. In general, business model structures converge around the logic of value generation of a reference system (e.g., organization, value chain, industry sector), which can be represented by different elements (Wirtz et al., 2016).

The fierce competitiveness of companies in an industry challenged to meet the needs of increasingly demanding consumers has required new ways of doing business. Taran et al. (2015) pointed out that global competition has forced companies to rethink their business models more frequently, given that innovating exclusively in new products and serving local markets is not enough to sustain competitiveness and ensure the company's survival. Therefore, business model innovation has become a considerable challenge for companies. Although many

managers are eager to consider more radical changes in their business model, they often do not know how to articulate the existing or desired business model and, even less, understand the possibilities of innovating it (Taran et al., 2015).

Innovative business models (IBMs) can take two forms: designing an entirely new business model or reconfiguring the elements of an existing one (Zott and Amit, 2010). By changing the business model elements, an organization can change how it is connected to external stakeholders and engages in economic exchanges to create value for its partners (Zott and Amit, 2008). Innovating the business model can help coordinate technological and organizational innovations that engage stakeholders within the value network (Zott et al., 2011). The dynamic process of the IBM can occur at different intensities and is related to the degree of novelty introduced (i.e., "new to the firm" or "new to the industry") or the scope of changes (i.e., individual components or systemic/architectural structure) (Foss and Saebi, 2017). Furthermore, different internal or external triggers, such as changes in the competitive environment or legislations, can stimulate changes in the business model.

Pieroni et al. (2019) recently highlighted that IBM is receiving increasing attention in specific areas (e.g., sustainability, CE, servitization, and digitization). In addition to generating superior customer value to gain competitive advantage and capture economic value, a sustainability-oriented business model also seeks to contribute positively to the environment and society (Stubbs and Cocklin, 2008; Lüdeke-Freund, 2010). In order to achieve a more sustainable business model, the CE can provide a path for business managers, and circular business models can enable economically viable ways to continuously reuse products and materials by using renewable resources wherever possible (Bocken et al., 2016).

A circular business model can be defined as the logic of how an organization creates, delivers, and captures value with and within closed material loops (Mentink, 2014). The idea is that an IBM does not need to close material cycles within its internal system boundaries, but it can also be part of a system of business models that, together, close a material cycle that can be considered circular (Mentink, 2014). Circular business model innovations are by nature networked: they require collaboration, communication, and coordination within complex networks of interdependent but independent actors or stakeholders (Antikainen and Valkokari, 2016).

Circular business models will gain an increasing competitive advantage in the coming years because they create more value from each resource unit than the traditional and linear "provide-discard" model. Hence, accelerating scaling may lead to substantial macroeconomic benefits and open up new opportunities for corporate growth (Ellen Macarthur Foundation, 2014). As a response to growing pressure on our natural resources, the CE aims to create various types of value with the ultimate goal of achieving a more effective and resource-efficient economic system (Ellen Macarthur Foundation, 2015). In this sense, companies must modify their business models to contribute to circularity; an innovative CE-oriented business model incorporates CE principles or practices as guidelines for business model design (Pieroni et al., 2019). This integration can take place, as explained by Urbinati et al. (2017), through

downstream circular changing capture and delivery from new revenue and customer interface schemes, for example, with pay-per-use models, upstream circular changing value creation systems, for example using reverse logistics, or combining upstream and downstream principles.

Business model innovation is the new way of creating, delivering, and capturing the value achieved by changing one or several components of the business model (Osterwalder and Pigneur, 2010). In this sense, it becomes evident that radical innovations and disruptive business models are required to address current challenges and move toward the CE model (Boons et al., 2013). From a strategic perspective, large companies already understand the need for business model innovations to ensure survival and growth as they deal with the external threat of continuous innovation (Blank, 2013). The CE requires managers to think differently: instead of thinking about the product itself, they need to think about systems around products and reinvent the way they generate revenue, creating and maintaining value over time (Bakker et al., 2014).

Aminoff et al. (2017) proposed a framework based on the assumption that business model innovation plays a critical role in creating new (disruptive) business ecosystems and opening new markets for a CE, where business model co-innovation is identified as crucial for the system-level changes required for CE. The authors offer a categorization and division of business model innovation into value creation innovation, new proposition innovation, and value capture innovation (Aminoff et al., 2017). Nußholz (2018) suggested examples of innovating the business model to achieve circularity from the three dimensions of business model values: value proposition, value creation and delivery, and value capture. The author developed a tool to help design business models that maintains and capitalizes on the value embedded in products for as long as possible, integrating business model thinking with circular principles to support business model planning throughout a product's life cycle (Nußholz, 2018).

In another study, Lüdeke-Freund et al. (2019) analyzed 26 circular economy business models (CEBMs), starting with defining their key business model dimensions and identifying the specific characteristics of these dimensions. These authors identified a wide range of business model design options and proposed six main CEBM patterns with the potential to support closing resource cycles: repair and maintenance, reuse and redistribution, refurbishment and remanufacturing, recycling, cascading and reuse, and organic feedstock business model patterns (Lüdeke-Freund et al., 2019). Similarly, Geissdoerfer et al. (2020) sought to contribute to reducing the conceptual lack of clarity and mapping the research landscape, providing a more solid foundation for the emerging field of circular business model innovation and contributing to greater clarity and simplicity in communicating what circular business models are and how they are innovated. Following the formalized value logic from value proposition, value creation and delivery, and value capture, the authors relied on strategies to circulate, extend, intensify, and dematerialize (Geissdoerfer et al., 2020).

BUSINESS PERFORMANCE

To measure business performance, organizations use indicators that, in most cases, are represented by quantifiable measures. Business performance indicators seek to evaluate the results achieved by companies from the established strategies to develop new plans and/or improvement proposals. Performance is a parameter used to quantify the efficiency and/or effectiveness of past actions and “the ability of the organization to achieve its goals by using its resources efficiently” (Neely et al., 2002; Daft and Marcic, 2004, p.10).

Several studies support that circular activities lead to better company performance (Zhu et al., 2010; Khan et al., 2020; Scarpellini et al., 2020). In the study by Gusmerotti et al. (2019), for example, the different advantages for companies that adopt the CE principles were identified, including the improvement of the brand and customer satisfaction (Ambec and Lanoie, 2008; Darnall and Sides, 2008), that we can associate with market performance, reduced environmental impact (Manninen et al., 2018; Nußholz, 2018), associated with environmental performance, increased competitive performance (Iraldo et al., 2009), related to market performance, and reduced dependence on the supply of raw materials together with less exposure to the risk associated with it (Winn and Pogutz, 2013; Kalaitzi et al., 2018), which can be related to production performance.

The Ellen Macarthur Foundation (2015) also cites that the CE drives innovation and that the benefits of a more innovative economy include high rates of technological development, improvement in processes and materials, efficient use of energy, and opportunities for financial gains for businesses companies.

For companies, the CE provides the opportunity for new products and ventures, or even new business models (Korhonen et al., 2018), in addition to a more sustainable image, which can be favorable to the company's marketing (Leitão, 2015; Korhonen et al., 2018). In addition, the CE can contribute to reducing the cost of waste disposal and environmental risks (Ellen Macarthur Foundation, 2015; Leitão, 2015; Korhonen et al., 2018), contributing to production performance and, consequently, a financial performance.

However, Ritzen and Sandstrom (2017) state that companies are reluctant to invest in the transition to the CE, as they consider the return to be uncertain and, mainly, because this return is not immediate.

Evaluating business performance requires defining the parameters that will be adopted. Indicators are instruments that help measure business performance and consist of one or more variables that, when associated, reveal broader meanings about the phenomena to which they refer, allowing the company's interests to be monitored and the planning of actions aimed at improving performance (Callado, 2010; Villas Bôas, 2011). In one of the most widely adopted models in research on innovation and sustainability, Gunday et al. (2011) highlighted the effects of innovation on different dimensions of business performance: innovation, production, market, and financial performance, revealing the positive effects of innovations on business performance.

As far as sustainable performance is concerned, the proposal developed by the Global Reporting Initiative (GRI) represents one of the most comprehensive scopes, being known and used by companies worldwide for sustainability reporting purposes. The GRI is an international non-governmental organization founded in 1997 and headquartered in the Netherlands, and its guidelines consist of the most widely used standard for sustainability reporting (Brown et al., 2009; Prado-Lorenzo et al., 2009; Rasche, 2009; Skouloudis et al., 2009; Tsang et al., 2009; Levy et al., 2010; Marimon et al., 2012).

The GRI guidelines are divided into economic, environmental, and social categories, and each category includes

information on management approach and a corresponding set of core and additional performance indicators. The core indicators consider aspects relevant to most organizations, and the additional indicators represent emerging practices or address issues that may be relevant to certain organizations (Global Reporting Initiative, 2016). With regard to the CE, the prevailing research emphasizes that by adopting a CE approach, organizations can achieve benefits by simultaneously and holistically addressing the economic, environmental, and social dimensions of sustainable development (Fonseca et al., 2018). Currently, the focus of these discussions has shifted from simplistic arguments about why CE is good to understanding

Performance	Variable
Innovative performance	Renewal of the administrative system in tune with the business environment
	Quantity of innovations introduced in work processes and methods
	Quantity of new projects in products and services
	Quality of the new products and services introduced
	Number of innovations under intellectual property protection
Production performance	Production flexibility (volume)
	Production and delivery speed
	Reduction in production costs
	Quality and compliance
Market performance	Total sales
	Market share
	Customer satisfaction
	Brand value
Environmental performance	Reduction in the emission of hazardous substances, waste, and pollutant gases
	Improvements in recycling and water reuse processes
	Increased use of clean and renewable energies (solar, wind, among others)
	Reduction of fossil fuel consumption
	Reduction of lawsuits resulting from environmental violations
	Increased use of materials from recycling
Economic and financial performance	Reduction of accidents with environmental damage
	Reduction of expenses with electric power and water consumption
	Increased overall company profitability
	Increase in sales volume
	Reducing the level of indebtedness
	Financial or material/product/service donations to local communities and/or for environmental protection
	Increased investment in research, development, and training
Reduction or elimination of cases of corruption, bribery, fraud, or illicit financing	
Social performance	Generation of work and income
	Reduction of work-related fatal and non-fatal accidents
	Reduction of the rate of work-related injuries, occupational diseases, lost days, absenteeism
	Reducing the rate of employee turnover
	Reduction in the number of labor suits/fines
	Reduction or elimination of the number of cases of forced or child labor (in the industry with suppliers or the local community)
	Reducing pay inequalities between men and women
	Reduction in the number of complaints regarding products/services registered in the period
Purchasing products from local suppliers	

FIGURE 1 | Proposal of Gunday et al. (2011) and Global Reporting Initiative (2016).

more theoretically sophisticated justifications for the results achieved by implementing circular business models (Lahti et al., 2018). The proposal of Gunday et al. (2011) and Global Reporting Initiative (2016) are presented in **Figure 1**.

Therefore, it is worth investigating whether the implementation of new business models on the pillars of the CE can generate financial gains and thus contribute to issues related to business performance.

STUDY METHODS

This study proposes to analyze the relationship between circular business model innovation and business performance in Brazilian industrial chemical companies. The research is characterized as descriptive, quantitative in nature and designed through a survey with Brazilian chemical companies. Descriptive research aims to describe the characteristics of certain populations or phenomena (Gil, 2008) and is used to estimate the proportion of these characteristics or behaviors to verify the relationship between variables (Mattar, 1997). For Malhotra (2006), quantitative research seeks to quantify data and generally applies some form of statistical analysis, while the survey is a method of collecting primary data from individuals who report their attitudes and behavior through questionnaires or interviews (Adams and Lawrence, 2019).

According to the objectives presented herein, the variables analyzed were grouped into two key dimensions: circular business model and business performance. The circular business model was analyzed to identify the degree of business model innovation based on the CE strategies adopted. As for business performance, in turn, this paper proposes to analyze financial, innovative, production, market, and socio-environmental performance based on Gunday et al. (2011) and Global Reporting Initiative (2016).

The questionnaire consisted of closed questions and a Likert scale in which respondents indicated the score that best reflects their agreement with the degree of innovation of the circular business model, ranging from 1 (incremental) to 5 (radical) and, in relation to business performance, ranging from 1 (lowest degree of agreement) to 5 (maximum degree

of agreement). These variables were ordered from lowest to highest value and reclassified as low, medium, and high degree of modification in the business model and for low and high business performance. The conceptual research model is defined by identifying interdependent relationships between the degree of innovation in the circular business model and business performance (**Figure 2**).

Questionnaires were sent to the companies using SurveyMonkey software (cloud-based online survey development software) and an invitation letter clarifying the study's objectives. Telephone and social networking contacts were also made with the companies to clarify the purpose and importance of the survey. The target population consisted of 256 companies associated with the Brazilian Chemical Industry Association (ABIQUIM, 2018). In September 2020, first, ABIQUIM was contacted and the associated chemical companies were asked to contact the research. Subsequently, all member companies were contacted by telephone in order to identify the most appropriate person in charge to answer the questionnaire. From there, the questionnaire was sent via e-mail and subsequent calls were made requesting the answers. In the end, in June 2021, 57 questionnaires were received, representing 22.3% of the population surveyed. Although the rate of return is not considered high, the results obtained allow for a specific analysis of the characteristics and behavior of the companies studied. The evidence found cannot be extrapolated to the research universe considered.

The data collected were tabulated using the Microsoft Excel and Statistical Package for the Social Sciences (SPSS) software and analyzed using univariate analysis via descriptive analysis of the categories and variables that made up such multivariate categories using multiple correspondence analysis. Homals (homogeneity analysis) was used to perform the correspondence analysis, which is a technique applied to study the relationship between two or more nominal or ordinal variables (Pestana and Gageiro, 2008). The homogeneity analysis seeks to ascertain, through the interactions established between the multiple categories, positioned in a defined space as a function of the crossing of dimensions, if distinct groups are defined (Carvalho, 2004). If so, the intention is to find out

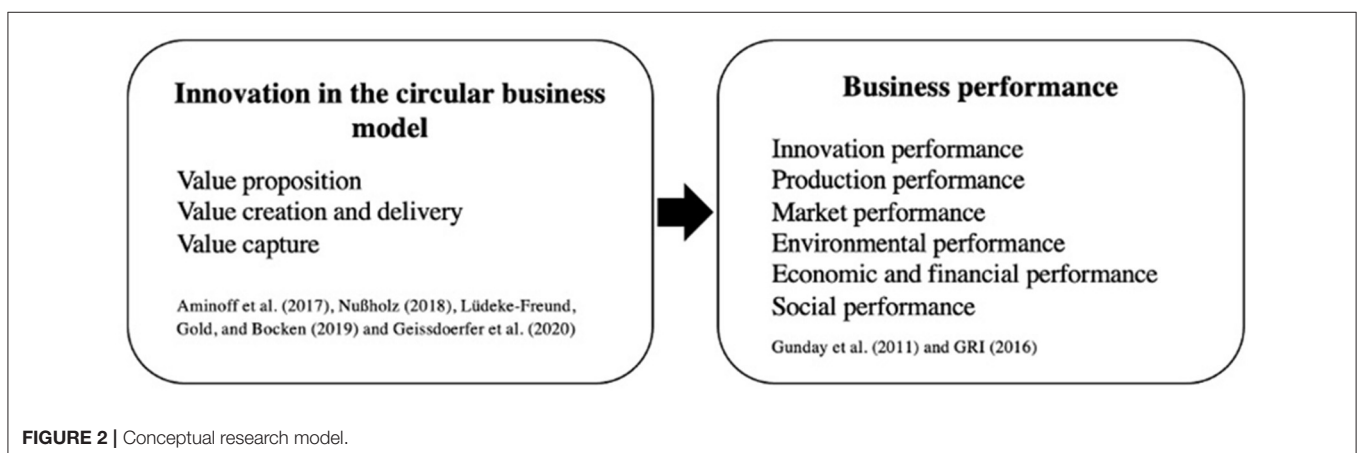


FIGURE 2 | Conceptual research model.

TABLE 1 | Sample characterization.

	Mean	Standard deviation	Coefficient of variation	Min.	Max.
Time in the company	9.64 years	8.164 years	85%	6 months	35 years
Time in the sector	12.0 years	10.193 years	85%	7 months	40 years
How long the company has been in business	Between 11 and 20 years old (19.3%)		Between 21 and 50 years old (56.1%)	Over 50 years old (24.6%)	
Gross operating revenue of the company in 2020	Below or equal to R\$ 360 thousand (7.0%) micro-enterprise	Above R\$ 360 thousand and up to R\$ 4.8 million (28.1%) small enterprise	Above R\$ 4.8 million and up to R\$ 300 million (49.1%) medium-sized enterprise	Above R\$ 300 million (15.8%) large enterprise	
Total number of employees	Up to 19 (12.3%) micro-enterprise	Between 20 and 99 (35.1%) small enterprise	Between 100 and 499 (33.3%) medium-sized enterprise	500 or more (19.3%) large enterprise	
Introduction to the innovation market in the last 5 years	Innovation in process (7.0%)	Product innovation (42.2%)	Innovation in product and process (36.8%)	Not applicable (14.0%)	
Primary responsibility for innovation activity	The company is solely responsible for the innovation activity (50.9%)	The company innovates in cooperation with other companies (15.8%)	The company innovates in cooperation with universities (7.0%)	The company innovates in cooperation with institutes (5.2%)	Not applicable (21.1%)
Origin of the company's controlling capital	National (73.7%)		Foreign (10.5%)	National and foreign (15.8%)	

how the groups are configured and positioned with each other. Categories close to the origin indicate that they are not important for defining the dimensions of the analysis plan (Carvalho, 2004). This method allows the results to be visualized through a perceptual map and the correspondence between the variables to be identified; Homals allows the interest in proving that the association between the degree of innovation in business models and sustainable innovation practices is illustratively and reliably satisfied, and revealing which groups of business performance variables are associated with a low, medium, or high degree of innovation of the circular business model. After explaining the methodological procedures used, we will analyze and discuss the results below.

ANALYSIS AND DISCUSSION OF THE RESULTS

The results of the study are analyzed below. The data on the characterization of the sample are first presented, followed by the descriptive statistics of the categories and variables that make up the degree of innovation in the circular business model and business performance. Finally, a multiple correspondence analysis (Homals) is performed to verify the relationship between the degree of innovation in the circular business model and business performance.

SAMPLE CHARACTERIZATION

The data from the sample studied are listed in **Table 1**. The data that characterize the companies surveyed indicate that, in relation to the profile of the respondents, the average time of work of the respondents in the company and sector is

approximately 9 and 13 years, respectively. This data shows the high experience of the professionals interviewed despite the considerable data variability.

The length of time companies have been in existence suggests traditional and conservative perceptions, considering that 80.7% of the companies are over 21 years old. The companies studied can be classified as micro-enterprises, small enterprises, medium-sized enterprises, and large enterprises. These data reflect that the sample comprises companies of all sizes. Therefore, understanding corporate behavior in relation to the degree of innovation of the circular business model and corporate performance in the sample studied can contribute to disseminating practices that provide greater corporate competitiveness for different realities of the sector in Brazil. By analyzing innovation-related characteristics, the data revealed that organizations have introduced product and process innovations in the last 5 years, evidencing that product innovation is linked to processes, contributing to greater business competitiveness. Regarding the primary responsibility for the innovation activity, there is a division between internal and external responsibility, since approximately half of the companies analyzed are the main funders of the innovative activity, while the other half work in partnership with other companies, universities, and institutes. From the characterization of the sample, the mean, standard deviation, and coefficient of variation of the categories and variables studied are further analyzed.

DESCRIPTIVE ANALYSIS OF CATEGORIES AND VARIABLES

The mean, standard deviation, and coefficient of variation of the seven categories and variables that make up each one in

TABLE 2 | Descriptive analysis of categories and variables.

Categories and variables	Mean	Standard deviation	Coefficient of variation (%)
Degree of innovation of the circular business model	3.0	1.113	36.9
Innovative performance	3.8	0.922	24.3
Renewal of the administrative system in tune with the business environment	3.8	1.225	32.0
Quantity of innovations introduced in work processes and methods	3.7	1.114	30.3
Quantity of new projects in products and services	3.8	1.184	31.6
Quality of new products and services introduced	4.2	0.991	23.4
Number of innovations under intellectual property protection	3.5	1.206	34.4
Production performance	4.2	0.661	15.6
Production flexibility (volume)	4.2	0.826	19.9
Production and delivery speed	4.3	0.774	18.1
Reduction in production costs	3.9	0.986	25.2
Quality and compliance	4.6	0.672	14.5
Market performance	4.4	0.528	12.1
Total sales	4.3	0.636	14.7
Market share	4.1	0.824	20.0
Customer satisfaction	4.6	0.563	12.2
Brand value	4.5	0.690	15.4
Environmental performance	3.9	0.851	21.8
Reduction in the emission of hazardous substances, waste, and pollutant gases	4.3	0.883	20.8
Improvements in recycling and water reuse processes	4.2	0.906	21.5
Increased use of clean and renewable energies (solar, wind, among others)	3.1	1.434	46.0
Reduction of fossil fuel consumption	3.6	1.161	32.6
Reduction of lawsuits resulting from environmental violations	4.3	1.087	25.1
Increased use of materials from recycling	3.7	1.143	31.1
Reduction of accidents with environmental damage	4.5	0.825	18.4
Economic and financial performance	4.0	0.794	20.1
Reduction of expenses with electric power and water consumption	3.7	1.185	31.7
Increased overall company profitability	4.1	0.824	20.0
Increase in sales volume	4.1	0.811	19.6
Reducing the level of indebtedness	4.2	0.950	22.7
Financial or material/product/service donations to local communities and/or for environmental protection	3.4	1.438	42.5
Increased investment in research, development, and training	3.8	1.125	29.5
Reduction or elimination of cases of corruption, bribery, fraud, or illicit financing	4.5	1.044	23.5
Social performance	4.3	0.628	14.6
Generation of work and income	4.3	0.890	20.6
Reduction of work-related fatal and non-fatal accidents	4.7	0.649	13.9
Reduction of the rate of work-related injuries, occupational diseases, lost days, or absenteeism	4.5	0.782	17.3
Reduction in employee turnover	4.1	0.879	21.6
Reduction in the number of labor suits/fines	4.4	0.865	19.9
Reduction or elimination of the number of cases of forced or child labor (in the industry with suppliers or the local community)	4.8	0.866	18.2
Reducing pay inequalities between men and women	4.4	0.805	18.5
Reduction in the number of complaints regarding products/services registered in the period	4.3	0.916	21.4
Purchasing products from local suppliers	3.8	1.080	28.7

relation to the variable reflecting the degree of innovation of the companies' circular business model and business performance are presented in **Table 2**. The variables were measured using a five-point Likert scale for the degree of business model innovation and for those related to business performance.

The results showed that business model innovation toward the CE had an average score of 3, which implies that the impact ranges from medium to high. In addition, this variable showed acceptable variability, revealing that this reality is uniformly present among the industrial chemical companies analyzed.

TABLE 3 | Variables and indicators of correspondence analysis.

Variables	Indicators
Degree of innovation of the circular business model	Low
	Medium
	High
Business performance	Low
	High

As for business performance, the most outstanding performance values among the analyzed companies were market, social, and production performance. Regarding market performance, customer satisfaction and brand value stood out. Social performance was driven by the reduction or elimination of the number of cases of forced or child labor with suppliers and the local community, the reduction in the number of fatal and non-fatal accidents at work, the reduction of injuries, illnesses, and absenteeism, the reduction in the number of labor lawsuits or fines, and the reduction of wage inequalities between men and women. Finally, in production performance, quality and compliance, and production and speed of delivery stood out.

Other dimensions, including environmental performance and economic and financial performance, despite presenting lower means than the others, also had outstanding variables, such as the reduction of accidents with environmental damage and reduction of lawsuits resulting from environmental damage (environmental performance), and the reduction or extinction of cases of corruption, bribery, fraud, or illicit financing (economic and financial performance).

Nevertheless, performance variables such as increased use of clean and renewable energy (environmental performance) and financial or material/product/service donations to local communities and/or environmental protection (economic and financial performance) presented the lowest means. Moreover, all variables and dimensions of business performance presented coefficients of variation with low or moderate response variability (below 50%). Finally, the relationship between the degree of innovation in the circular business model and business performance is verified through multiple correspondence analyses.

CORRESPONDENCE ANALYSIS OF THE CATEGORIES

The relationship between the degree of business model innovation from circular strategies and business performance was analyzed by multiple correspondence analysis (homals). The initial analysis model was formed by the categories associated with the variable representing the degree of innovation of the circular business model and the categories of business performance. These new variables were then divided into indicators (Table 3).

By applying the multivariate analysis technique (homals), dimension 1 showed eigenvalues of 4.04, whereas dimension 2 had a value of 1.138. The values enabled us to identify

TABLE 4 | Measures of discrimination of correspondence analysis.

Categories	Dimension 1	Dimension 2
Degree of innovation of the circular business model	0.577	0.775
Innovative performance	0.543	0.130
Production performance	0.654	0.018
Market performance	0.531	0.051
Environmental performance	0.516	0.056
Economic and financial performance	0.675	0.024
Social performance	0.543	0.085

the clear disaggregation of different categories, separating each variable and forming differentiated groups of variable categories. The discrimination measures of the variables according to the dimensions are listed in Table 4.

The correspondence relations among the categories of variables and indicators analyzed are presented in Figure 3.

The data presented allow us to make some considerations about the relationship between the degree of innovation in the companies' circular business model and business performance:

- (1) The high degree of innovation in the circular business model is associated with high market, production, economic and financial, and social performance.
- (2) The medium degree of innovation in the circular business model is associated with low market, production, economic and financial, and social performance.
- (3) The low degree of innovation in the circular business model is associated with low innovation and environmental performance.

The results revealed that a high degree of innovation in the circular business model indicates a high market performance (total sales, market share, customer satisfaction, and brand value); high production performance (production flexibility, production and delivery speed, reduction in production costs, and quality and compliance); high economic-financial performance (reduction of expenses with electric power and water consumption, increased overall company profitability, increase in sales volume, reducing the level of indebtedness, financial or material/product/service donations to local communities and/or for environmental protection, increased investment in research, development, and training, and reduction or elimination of cases of corruption, bribery, fraud, or illicit financing); and high social performance (generation of work and income, reduction of work-related fatal and non-fatal accidents, reduction of the rate of work-related injuries, occupational diseases, lost days, or absenteeism, reduction in employee turnover, reduction in the number of labor suits/fines, reduction or elimination of the number of cases of forced or child labor, reducing pay inequalities between men and women, reduction in the number of complaints regarding products/services registered in the period, and purchasing products from local suppliers). These results corroborate the findings of some authors (Leitão, 2015; Korhonen et al., 2018) who report that the CE provides the opportunity a more sustainable image, which can be

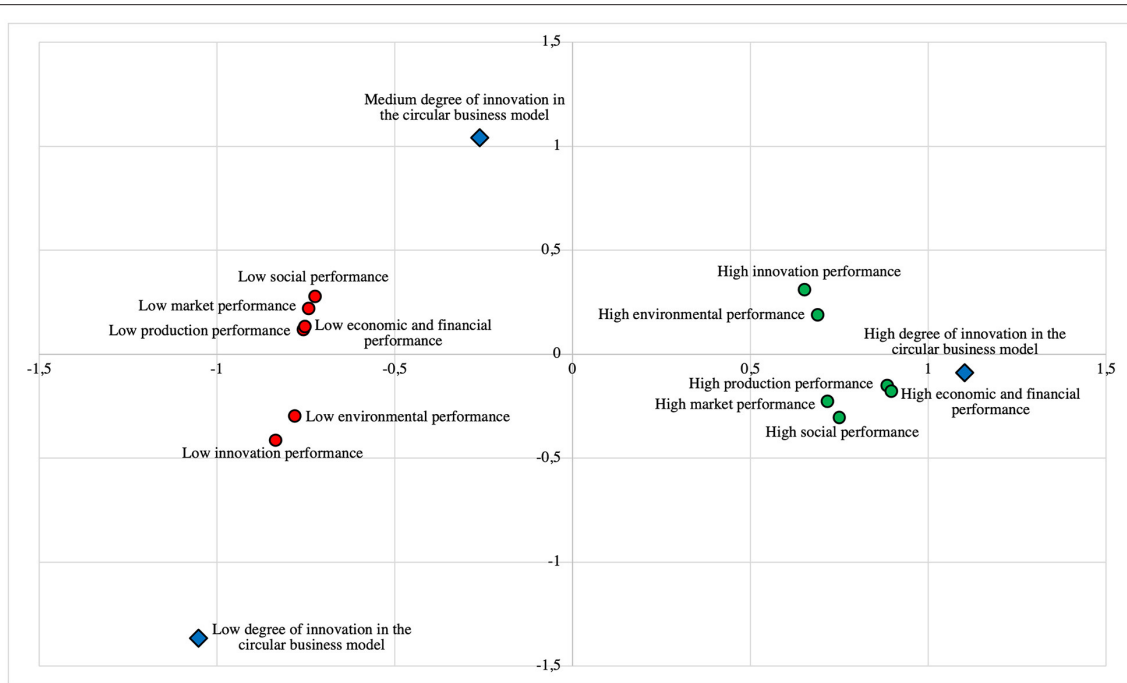


FIGURE 3 | Analysis of correspondence among categories.

favorable to the company's marketing, and to reducing the cost of waste disposal and environmental risks. According to these reports, superior market and production performance can be explained from a greater degree of innovation toward a circular business model.

Another result revealed in our study was that innovation in the circular business model also contributes to economic and financial performance. This finding agrees with some studies (Ellen Macarthur Foundation, 2013; Lehmann et al., 2014; European Environment Agency, 2016; Geissdoerfer et al., 2017; Masi et al., 2017), which reported that the direction of the CE could contribute for superior business performance, as some studies predict that the CE will positively affect the environment and economic growth. However, a high degree of innovation in the circular business model does not contribute to high environmental performance as expected.

For companies with a medium degree of innovation in their circular business model, a behavior geared toward low market performance, low production performance, low economic and financial performance, and low social performance was observed. Companies with a low degree of business model innovation, on the other hand, exhibit low innovative performance (renewal of the administrative system in tune with the business environment, quantity of innovations introduced in work processes and methods, quantity of new projects in products and services, quality of new products and services introduced, and number of innovations under intellectual property protection) and low environmental performance (reduction in the emission of hazardous substances, waste, and pollutant gases, improvements

in recycling and water reuse processes, increased use of clean and renewable energies (solar, wind, among others), reduction of fossil fuel consumption, reduction of lawsuits resulting from environmental violations, increased use of materials from recycling, and reduction of accidents with environmental damage).

CONCLUSIONS

According to our findings, the analyzed industrial chemical companies have medium to high degrees of business model innovation toward the CE, despite high response variability. These companies showed outstanding market performance with customer satisfaction and brand value, social performance, low forced or child labor, accidents and injuries, labor lawsuits, gender pay gaps, and improved production performance with quality, compliance, and delivery speed.

In addition, when analyzing the relationship between the degree of innovation in the circular business model and business performance in the Brazilian chemical industries, it was evident that a more proactive stance in their business model toward the CE is related to better market and productive performance, economic and financial, and social. This confirms that a significant shift from linear economic logic to a more innovative logic such as CE is associated with superior business performance.

When it comes to companies with a medium degree of innovation in the circular business model, a behavior directed

toward low environmental and low economic and financial performance is observed, revealing the need for a more radical change in the way of doing business as opposed to the production system linear, since a partial shift to a circular business model was not related to high performance rates. Likewise, the low degree of innovation in the circular business model represented low innovative performance and low environmental performance. Analyzing environmental performance and innovative performance, the results show that a high degree of innovation in the business model is not associated with a high environmental performance and a high innovative performance, however, a low degree of innovation in the business model it was associated with a low environmental performance and a low innovative performance. This means that the chemical industries analyzed that changed their business model toward the CE did not present better environmental and innovative results, while the chemical industries that did not change their business model toward circularity presented worse environmental and innovative performance than the others. In other words, only the renunciation or low adherence to a circular business model is related to environmental performance and innovative performance.

Based on the data here, it is recommended that managers and decision makers of executive companies strategically and proactively insert innovation and the CE into their

business models. However, this study found several limitations, including an inability to generalize the superior and discussed results. Therefore, as a suggestion for future research, we recommend expanding this study to other realities and even to other business sectors to assess the relationship between the degree of innovation of the circular business model and business performance.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

FM: data analysis. CG: general orientation. JK: construction of the framework and the study method. AP: construction of the framework and the study method. LD: data collection. TL: data collection. All authors contributed to the article and approved the submitted version.

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