REVISTA DE ADMINISTRAÇÃO DA UFSM
Brazilian Journal of Management
ReA UFSM

UFSM

ISSN 1983-4659
OPEN ACCESS

Rev. Adm. UFSM, Santa Maria, v. 17, spe 1, e11, 2024 https://doi.org/10.5902/1983465987445
Submitted: 04/11/2023 • Approved: 10/25/2024 • Published: 11/19/2024

Original Article

Relationship between circular economy practices and process innovation: an analysis of textile organizations in Santa Catarina

Relação entre as práticas da economia circular e a inovação em processos: uma análise nas organizações têxteis de Santa Catarina

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ABSTRACT

Objective: To evaluate the relationship between circular economy practices and process innovation.
Methodology: This is a quantitative study using descriptive, exploratory, and confirmatory approaches. It is a cross-sectional study employing a survey typology. The study utilized a questionnaire encompassing the dimensions of process innovation and circular economy (CE), applied to a sample of 135 textile industry companies. Data analysis was conducted through Structural Equation Modeling (SEM).
Findings: There is an evident positive relationship between CE practices and process innovation. The results indicate that the surveyed textile industries are in the initial phase of implementing their CE practices.
Research Limitations: The use of a non-probabilistic sample, thus hindering the generalizability of the results and focusing solely on process innovation.
Theoretical Implications: Development and psychometric validation of the questions guiding the study of circular economy application through the ReSOLVE model, as well as integration with the construct of process innovation.
Social Implications: By applying the principles of the circular economy through the ReSOLVE model, there is optimization of production, and coupled with technological development, textile industries achieve better process innovation outcomes.
Managerial Implications: Real evidence from the application of the ReSOLVE model demonstrates the cause-and-effect relationship between the circular economy and process innovation.
Originality/Value: The theoretical relationship between CE and innovation and the psychometric validation process of the questions guiding the study of EC application through the ReSOLVE model.

Keywords: Circular economy; Process innovation; Textile industry; Waste; ReSOLVE

RESUMO

Objetivo: verificar a relação entre as práticas de economia circular (EC) e a inovação em processos na indústria têxtil.
Metodologia: o estudo utilizou um questionário composto pelas dimensões inovação em processos e EC, aplicado em uma amostra de 135 empresas da indústria têxtil. A análise dos dados foi realizada pela Modelagem de Equações Estruturais (MEE).
Descobertas: evidencia-se uma relação positiva entre as práticas de EC com a inovação em processos, os resultados apontam uma relação positiva. Os resultados mostram que as indústrias têxteis pesquisadas estão em fase inicial de implementação de suas práticas de EC.
Limitação da pesquisa: utilização de uma amostra não probabilística, desse modo, inviabilizando a geração dos resultados obtidos e pela abordagem apenas da inovação em processo.
Implicações teóricas: desenvolvimento e validação psicométrica das questões que norteiam o estudo da aplicação da economia circular, por meio do modelo ReSOLVE, bem como, a integração com o constructo de inovação em processos.
Implicações sociais: ao aplicar os princípios da economia circular por meio do modelo ReSOLVE há otimização da produção e, aliado ao desenvolvimento tecnológico, as indústrias têxteis obtêm melhores resultados de inovação em processos.
Implicações gerenciais: as evidências reais da aplicação do modelo ReSOLVE mostram a relação de causa e efeito entre a economia circular e a inovação em processos.
Originalidade/valor: a relação teórica entre EC e inovação e processo de validação psicométrica das questões que norteiam o estudo da aplicação da EC, por meio do modelo ReSOLVE.

Palavras-chave: Economia circular; Inovação em processos; Indústria têxtil; Resíduos; ReSOLVE

INTRODUCTION

Population growth over the years has consequently led to a substantial increase in production within the textile industries. Globally, the fashion industry produces between 100 and 150 billion clothing items annually (Smith, 2023), surpassing 100 million tons of consumption of both synthetic (chemical) and natural textile fibers each year. Of this amount, more than two-thirds of textiles are discarded in landfills at the end of their use, and only 15% are recycled (Shirvanimoghaddam et al., 2020). In financial terms, this waste represents $3 billion in clothing and textile products deposited in landfills annually (Saha et al., 2021).

The United Nations (UN) projects that the consumer class will triple in the coming years, prompting studies on new production methods (Weetman, 2019). In this context, changes in current practices within the textile industry are necessary due to the ecological degradation caused over the years (Henninger et al., 2016). The sector needs to undergo transformations, with new actions to be implemented in the industrial landscape at profound levels, considering short, medium, and long-term horizons.

The foundation for altering the industrial landscape stems from the globalization of the clothing supply chain, which led to the development of the “fast fashion” business model. This model allows consumers to purchase clothing in exorbitant quantities (Gwilt, 2014). Fast fashion leads to rapid acquisition and obsolescence of products, increasing the flow of resources in a way that directly harms the environment (Fletcher & Grose, 2011).

Environmental degradation occurs mainly due to the traditional production model, known as linear, which involves resource extraction, production, and disposal after use (Weetman, 2019). This model is commonly used by a large portion of textile industries. However, textile and apparel industries play an important role in economic progress by providing jobs and fostering regional development (Ellen MacArthur Foundation [EMF], 2017). Therefore, there is a need to create models based on production principles that adopt short and closed cycles (Korhonen et al., 2018). In this context, adopting circular economy practices can aid in implementing this new model while simultaneously increasing operational performance.

The circular economy can be established in all phases of a product’s life cycle, from product design and manufacturing, through marketing and consumption, to waste management, reuse, and recycling (Wiegand & Wynn, 2023). However, this process implies a paradigm shift, demanding a new way of organizing the production flow (Alonso-Muñoz et al., 2021; Luthra et al., 2022) based on a systemic approach that evaluates the interconnections between produced energy, extracted materials, and the natural environment (EMF, 2013). According to Barros et al. (2021), the circular economy requires a structural change that reshapes the production process and organizational culture.

Ashby (2018) describes the circular economy (CE) as a production model that recovers value from tangible commodities through a closed loop, utilizing the reuse and restoration of resources to enhance performance. However, to implement circular practices, companies need to align their strategies with circular economy principles and rethink aspects such as positioning, value proposition, and sustainable differentiators (Bocken & Short, 2020). This presents a significant challenge, as it requires not only internal changes but also a rethinking of how products are offered to customers (Bocken & Short, 2020).

The transition to a circular economy requires its principles to be demonstrated through actions (Suárez-Eiroa et al., 2019) by implementing various practices along the supply chain that help retain the value of utilized resources (Vinante et al., 2021). To assess the levels of circular economy practices, it is necessary to investigate how circular business models are implemented within companies (Brown et al., 2020).

Transitioning to a circular economy involves adopting parameters for incorporating processes and solutions that effectively transform the production model (Smol et al., 2017). In this scenario, implementing process innovations is essential because constant changes in the business environment require continuous adaptation to adjust to environmental conditions (Eisenhardt & Martin, 2000), promoting increased efficiency and effectiveness in production processes (Tang et al., 2013). Thus, process innovation meets specific needs to continually improve existing processes and structures, ensuring that scarce resources are utilized in the best possible way (Zhao, 2005).

This study aims to evaluate the relationship between circular economy practices and process innovation. To measure process innovation, the model was based on the guidelines from the OECD's (2005) innovation data collection manual, and for the circular economy, it considered the adaptation of the ReSOLVE model proposed by Lewandowski (2016).

Finally, this study is justified by the observation that the circular economy is still fragmented in the literature (Pieroni et al., 2019), with few attempts to propose models for evaluating circular economy practices (Garza-Reyes et al., 2019). Additionally, the literature indicates that circular business models are in the initial stages, with little attention to the challenges arising from implementing the circular economy and methods for performance evaluation (De Angelis, 2021). In the context of innovation, there are gaps in the literature regarding how companies can enact internal changes (Vashevko, 2019).

LITERATURE REVIEW

Circular Economy

Due to demographic growth and the exponential increase in the purchasing power of the middle class, there is a need for new business models to replace the linear production model. This traditional model excessively utilizes non-renewable natural resources and delivers fast-consumption products in a manner that the planet cannot sustain. The pressure to raise awareness about finite resources has led to rethinking the linear economic model—a traditional production system involving resource extraction, production, and disposal after use (Weetman, 2019). To address this, the economy should leverage nature's cycles to preserve materials, energy, and nutrients for economic use and limit the production flow to a level that nature can tolerate (Korhonen et al., 2018).

To mitigate the impacts caused by the traditional production system, various theories have been developed aiming to preserve resource durability through the concept of a closed loop. Among these theories is the circular economy, which, according to the Ellen MacArthur Foundation (EMF, 2015), is a restorative or regenerative industrial system that replaces the concept of end-of-life with restoration. It encourages shifting from traditional energy sources to renewable energy, eliminates the use of toxic chemicals, and promotes reuse and waste elimination through superior design of materials, products, and systems (EMF, 2015). However, the transition to a circular economy is challenging because it requires financial capacity and technical skills, as well as fundamental changes in consumer behavior, business models, institutions, and governance (Maaß & Grundmann, 2018).

Thus, the central objective of the principles of the circular economy is to fully capitalize on product reuse by restoring material flows through closed loops, reusing valuable resources, and reducing waste. Unlike the linear model, the circular economy aims for economic development in conjunction with environmental protection (Gardetti & Senthilkannan, 2019).

Therefore, the circular economy follows a rational use of resources, and for its adoption by business models, natural resources (raw materials) must be used in such a way that the manufacturing of products for human consumption maintains balance to avoid generating waste (Lacy et al., 2020). When waste is generated, it can be transformed through technical and biological processes into new resources to be fully reused by ecosystems via system feedback (Manninen et al., 2018). By using resources rationally, the circular economy can generate gains and increase resource-use efficiency. It can also bring substantial benefits to the economy, consumers, and companies by promoting solutions to the negative externalities exposed by the linear economy and fostering investments in innovations to build sustainable competitive advantage (Chen et al., 2019).

PROCESS INNOVATION

The term innovation has become essential both in the academic sphere and in the business world. We observe a world in constant transformation and immersed in global competition, where innovations emerge at a rapid pace and become obsolete just as quickly (Carvalho, 2009).

Process innovation is an indispensable task for organizations because customer needs, technologies, or sales channels are constantly changing (Piening & Salge, 2015). The vast majority of companies exist in environments that change dynamically. Thus, their innovation processes require adaptation to ensure proper alignment with environmental conditions (Eisenhardt & Martin, 2000). Although this change is inevitable and normal, continuous adaptation is necessary, which occasionally leads to the requirement of significant adjustments (Naveh, 2005).

Process innovation seeks to develop a business's capacity to create value in the production of products or services and refers to new or altered ways of offering them (OECD, 2005), generating cost reductions and shortening delivery times (Marzi et al., 2017).

Delivering products and services efficiently and effectively in terms of time, cost, and quality requires constant adaptation to future customer requirements and opportunities from new technologies (Tang et al., 2013). For process innovation to be successful, a company's needs must be properly analyzed, and system changes must be well-managed (Damanpour & Gopalakrishnan, 2001).

Implementing process innovations within an organization must consider several factors. Employees need to be willing to engage in continuous training and adapt to new routines due to the high volatility of procedures in corporations (Suvalova, Ashurbekov & Suvalov, 2021). Operations refer to distinct ways of execution, not just minor changes subject to incremental improvement (Jabbour et al., 2020). Thus, process innovation addresses an organization's ability to generate, adapt, and implement new or radically altered processes within itself (Pierce & Delbecq, 1977).

CIRCULAR ECONOMY AND PROCESS INNOVATION

The circular economy aims to close the production cycle, maximizing output results (EMF, 2017). Process innovation involves implementing a significantly different method of carrying out operations (Yang et al., 2015). Therefore, the circular economy seeks to promote innovations in production systems that optimize the consumption of materials and products to achieve a balance among the economy, the environment, and society (Sauvé et al., 2016).

For this, transitioning from the linear business model to a circular model is necessary, where circular economy practices are converted into innovation, thus characterizing the innovation of the circular business model (Linder & Williander, 2017).

Circular business models encourage innovation (Nussholz, 2020). Transitioning to business models where the created value is associated with the circular economy leads to incremental and disruptive innovations, transforming business logic (Jabbour et al., 2020). Companies can adopt circular practices to promote sustaining and disruptive innovation, resulting in significant improvements in products and services to generate circular business models (Tabbah & Maritz, 2019). In this way, innovations can turn linear processes into circular ones (Riesmeier, 2020).

To analyze circular practices, the Ellen MacArthur Foundation (2015) developed the ReSOLVE framework, which is based on circular economy practices. In this framework: **Re (Regenerate)**: Replacing non-renewable energies and materials with renewables, enabling the return of biological resources to the biosphere; **S (Share)**: Encouraging maximum product utilization through sharing among users, avoiding the purchase of unnecessary products; **O (Optimize)**: Aiming to increase the quality of manufacturing and remanufacturing, enhancing production efficiency, and minimizing waste generation from the production process; **L (Loop)**: Keeping components and materials in closed circuits, prioritizing remanufacturing; **V (Virtualize)**: Seeking product dematerialization to reuse mechanical and electronic components; **E (Exchange)**: Addressing the exchange of non-renewable materials for more advanced ones, combining innovative technologies to increase efficiency.

Studies focused on circular innovations indicate that companies need to radically rethink their products based on rigid specifications and consider closing the loop at the initial design stage (De Pauw et al., 2014). This leads to establishing clear goals during the project's initial phases to support process innovation (De Marchi, 2012).

Improving processes at an early stage can yield significant results by combining circular practices with innovations, enhancing the company's market positioning (Mokhtar et al., 2019). Besides increasing productivity, process innovations ensure that resources are used efficiently (Christensen et al., 2016). Efficiency is directly linked to narrowing and closing production cycles, which minimizes waste through reduction, reuse, and recycling, consequently reducing the environmental impact generated by the company (EMF, 2015).

METHODOLOGY

To achieve the objective of evaluating the relationship between circular economy practices and process innovation, this study was classified as descriptive and cross-sectional research with a quantitative approach. The research aimed to measure the relationship between the circular economy and process innovation. Data were collected through a questionnaire composed of 29 questions related to the circular economy and five questions related to process innovation.

To measure the circular economy, the ReSOLVE model (Regenerate, Share, Optimize, Loop, Virtualize, and Exchange) proposed by EMF (2015) was used as a basis. Sehnem et al. (2021), based on the adaptation proposed by Lewandowski (2016), conducted validation and linguistic adaptation procedures for the questionnaire, resulting in a general model applied in qualitative procedures. For this research, given its quantitative approach, adjustments were made to the model proposed by Sehnem et al. (2021), with alterations to the questions to suit the investigated segment: managers of textile and apparel industries.

In this research, the construct of the circular economy was measured by the level of implementation of circular practices. A Likert-type scale was used for evaluation, ranging from 1 for “not implemented” to 5 for “implemented and with evidence of improvements.” To verify whether companies apply process innovation, the construct from OECD (2005) was utilized, where the measurement was also on a 5-point Likert scale, with 1 equating to “strongly disagree” and 5 to “strongly agree.” The practices involved in each dimension are described in **Table 1**.

Table 1 – Practices of circular economy

ReSOLVE Dimensions	Practices
Regenerate	- Shift to reusable and renewable materials and energy; - Recover, retain, and restore ecosystem health; - Return recovered biological material to the biosphere.
Share	- Share assets like cars, spaces, lighting; - Reuse and utilize materials already used by others; - Prolong life through maintenance, durability, and upgrades.
Optimize	- Improve product performance and efficiency; - Reduce waste in the production chain; - Leverage the use of big data, automation, and remote production control.
Loop	- Remanufacture products and components; - Recycle materials; - Anaerobically digest; - Extract biochemicals from organic waste.
Virtualize	- Directly dematerialize (goods like books, CDs); - Indirectly dematerialize (services).
Exchange	- Replace old materials with renewable ones; - Apply new technologies; choose new products or services.

Source: Adapted from EMF (2015)

The questionnaire related to the circular economy underwent psychometric validation, with the initial application of the Q-sort method, aiming to validate the construct concerning the content of the items, providing reliability to the data collection instrument (Moore & Benbasat, 1991). The Q-sort method is based on the perception of judges who have knowledge of the content domains explored in the research, offering contributions about the selected measurement scales. The agreement between the judges and the researchers' perspective attests to the substantive validity of the construct (Anderson & Gerbing, 1991; Ahmed et al., 2017). From this application, correlation indices between judges above 80% were obtained, with values above 65% being acceptable (Moore & Benbasat, 1991). The concordance index was also calculated, and after necessary adjustments, the tests continued. Finally, the reliability of the judges' classification was measured using the Kappa index (Cohen, 1960), which is the most commonly used reliability measure for validating the content of questionnaire items (Perreault & Leigh, 1989). Applying the Kappa classification formula composed by Landis and Koch (1977) yielded a Kappa coefficient above 81% for all questions related to the dimensions of this construct, considered perfectly agreeable.

The survey was sent by email, through a messaging app, and delivered in printed form to managers of textile and apparel industries in the state of Santa Catarina, from August 2022 to December 2022. The population of this study corresponds to 9,140 textile and apparel companies, of which 83.4% are classified as micro-enterprises, 13.9% as small, 2.4% as medium, and 0.3% as large (FIESC, 2021). The sample of 135 respondents, composed of production managers/directors or individuals involved in product development, is considered non-probabilistic based on accessibility.

After receiving the responses, refinement and definition of thresholds were carried out, as well as defining the degree of difficulty of each question based on Item Response Theory, using the software Winsteps Rasch version 5.1.4.0. Items are considered easy when endorsed by the majority of respondents and difficult when endorsed by the minority. Based on the analysis of the results and following the Rasch Model (Bond & Fox, 2020), six respondents were excluded.

An exploratory factor analysis was performed to validate the instrument, aiming to identify the best factor solution that represents the structure of interrelations among the variables (Fabrigar et al., 1999). In summary, it was verified that the measurement models possess validity, mostly presenting indicators convergent with what is advocated in the literature.

For data analysis, Structural Equation Modeling (SEM) was applied using the statistical software JASP 0.16.3.0. Subsequently, Confirmatory Factor Analysis (CFA) was conducted, as well as assessing the reliability of the constructs through Factor Loadings, R^2, p-values, Composite Reliability, Cronbach's Alpha, and Average Variance Extracted. After this initial evaluation, descriptive analyses of the sample were performed, and then the SEM technique was applied again to test the relationships between the research constructs.

ANALYSIS AND RESULTS

The research sample consisted of 135 companies from the textile and apparel segment in the state of Santa Catarina. **Table 2** shows the number of participating companies according to their textile division.

Table 2 – Research Sample by Textile Segment Division

Textile Division	Companies	Representation
Apparel	99	73,3%
Weaving	10	7,4%
Finishing	9	6,7%
Spinning	1	0,7%
Others	16	11,9%
Total	**135**	**100,0%**

Source: Research data (2022)

In this study, it is noted that all types of textile industries were included; however, companies in the apparel sector prevail in number, comprising about 73% of the respondentes.

REFINEMENT OF THE STRUCTURAL MODEL

Initially, Cronbach's alpha coefficient (α) was measured, where its degree reflects the covariance between the items of an instrument but tends to be influenced by the number of items and its dimensionality (Hair Jr. et al., 2018). The average variance extracted (AVE), which indicates how much the construct explains the set of items, was also analyzed; coefficients greater than 0.5 in each dimension can be referenced (Hair Jr. et al., 2018). Composite Reliability, which evaluates the quality of the structural model of an instrument and has been presented as a more robust indicator compared to Cronbach's alpha (Valentini & Damasio, 2016), was also considered, where a result above 0.7 is considered satisfactory (Hair Jr. et al., 2018).

All measurement models showed convergent validity with reliability indicators above 0.7 and average variance extracted above 0.5. For the "Loop" dimension, all results were satisfactory except for AVE, which was 0.484, whereas the literature recommends above 0.5; however, the indicator was very close to the recommended value. Differently, the "Share" dimension had an indicator of 0.399. **Table 3** shows all the results obtained.

Table 3 – Reliability of Research Constructs

First-Order Construct	Cronbach's Alpha	Composite Reliability	AVE
Regenerate	0.843	0,846	0,527
Share	0.743	0,762	0,399
Optimize	0.853	0,859	0,552
Loop	0.811	0,821	0,484
Virtualize	0.837	0,849	0,592
Exchange	0.879	0,881	0,65

Source: Research data (2022)

Note that the "Share" variable obtained an average variance extracted below the recommended values. This result is inferred to be due to the practices of this item not being adopted by most organizations, which aligns with studies conducted by Filho and Neves (2020), where low AVE values result from the lack of application of these practices.

After validating the measurement models, discriminant validity was performed (**Table 4**) using the method of Fornell and Larcker (1981).

Table 4 – Discriminant Validity

Constructo	1	2	3	4	5	6
Regenerate (1)	**0,726**					
Share (2)	,401**	**0,632**				
Optimize (3)	,672**	,377**	**0,7430**			
Loop (4)	,635**	,386**	,612**	**0,696**		
Virtualize (5)	,431**	,306**	,474**	,432**	**0,769**	
Exchange (6)	,559**	,304**	,588**	,610**	,627**	**0,806**

Source: Research data (2022)

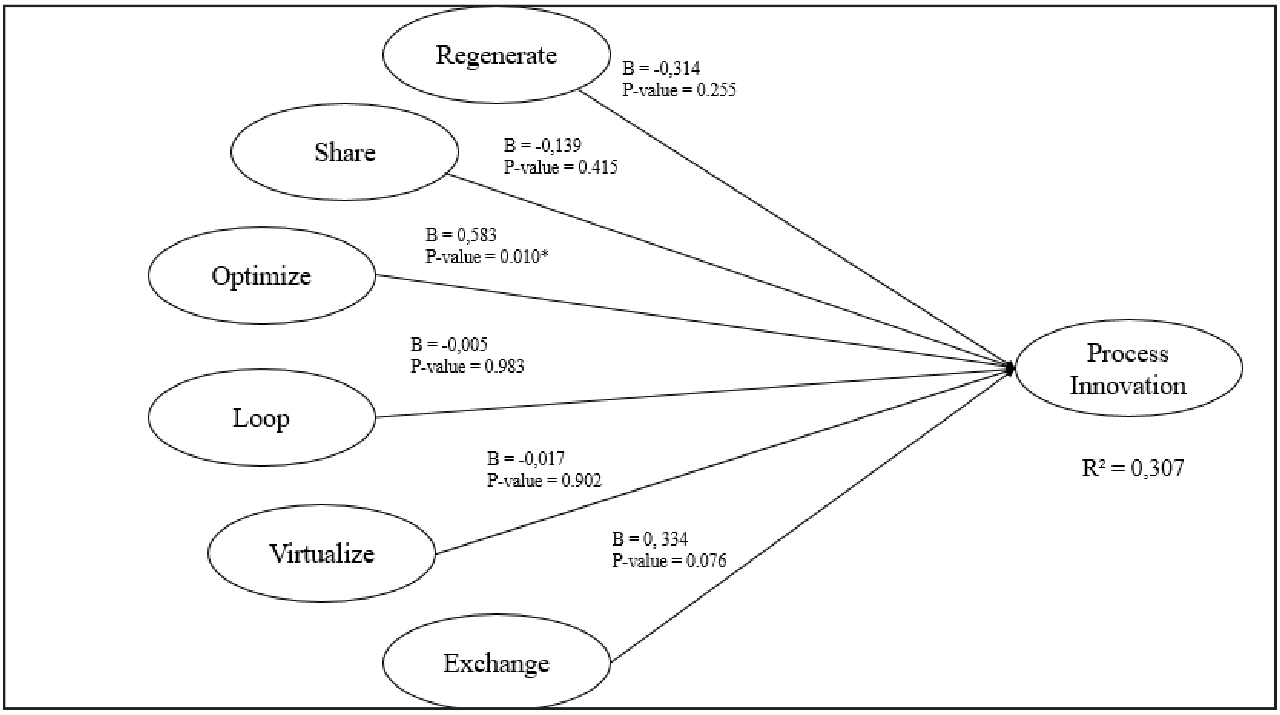
Through discriminant validity, it is observed that all measurement models are discriminant, meaning they are not multicollinear or presenting content overlap, since the square root of the AVE is greater than the correlation of the construct with the others.

STRUCTURAL MODEL ANALYSIS

After refinement and validations, this section presents the analysis of the structural model using Structural Equation Modeling (SEM). In this way, the correlations of the circular economy dimensions on the dependent variable —process innovation—were examined. Additionally, the direct impact of the circular economy on process innovation was analyzed.

The structural model measures the main focus of the present study, which is the relationship between circular economy practices and process innovation. **Figure 1** illustrates the research model with the regression results (β), p-value, and R^2.

Figure 1 - Research model



Source: Created by authors

The result of the structural model test is presented in **Table 5.**

Table 5 – Structural model test

Independent Variable	Dependent Variable	Regression Weight (β)	Standard Erro	*t-value*	*p-value*	R^2
Share	Process Innovation	-0.139	0.203	-0.816	0.415	0,307
Regenerate		-0.314	0.217	-1.138	0.255	
Optimize		0.583	0.166	2.574	0.010	
Loop		-0.005	0.201	-0.022	0.983	
Virtualize		-0.017	0.094	-0.123	0.902	
Exchange		0.334	0.127	1.773	0.076	

Source: Research data (2022)

From **Table 5,** it is broadly observed that only the "Optimize" dimension has a relationship with process innovation. Therefore, it can be said that this dimension alone is capable of explaining 30.7% of process innovation. It is the only one with significance greater than 95%, presenting a p-value < 0.05 and having a regression weight of $\beta = 0.583$. This result aligns with the study by Ceptureanu et al. (2018), where the "Optimize" dimension was found to be the most significant for managers.

The "Optimize" dimension encompasses five questions that are of paramount importance for generating process innovation. The first question addresses the program for enhancing performance and efficiency of processes. In the results highlighted by Rizzi et al. (2022), control procedures were identified, including initiatives for material efficiency, reduction in energy consumption, and management of waste from production. This study converges with the findings of Ceptureanu et al. (2018), who emphasized significant results regarding productive efficiency, reducing waste, and consequently increasing organizational performance.

The second question pertains to the program for reducing waste generation during the production/sales process. In line with Lazarevic and Valve (2017), aiming for zero waste based on closing loops would reduce the environmental impacts generated by industries. Moreover, this agrees with Ceptureanu et al. (2018), who aim to optimize processes with minimal waste. By implementing this practice, production costs can be minimized, generating process innovation.

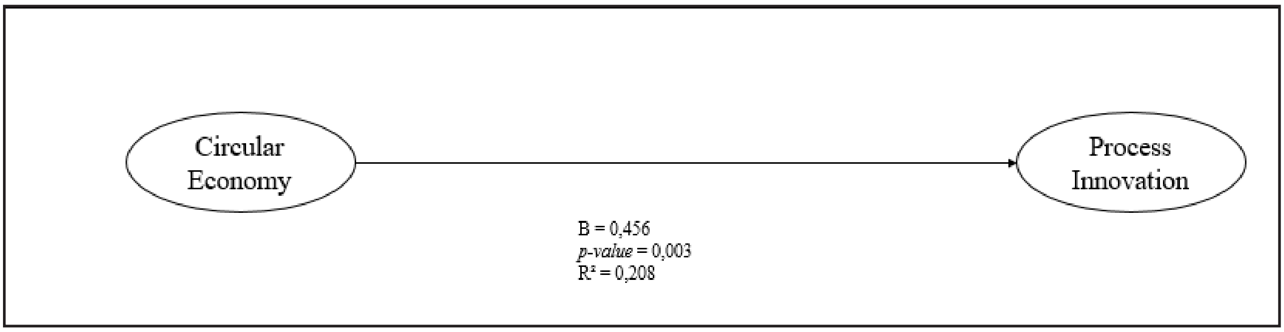
The third question relates to the use of information/monitoring systems based on technologies to verify performance. Similar to the studies by Rizzi et al. (2022), control procedures optimize production systems. Additionally, they can regulate environmental parameters such as resource consumption, toxicity, waste generation, greenhouse gas emissions, and energy efficiency through the automatic optimization of manufacturing processes (Jabbour et al., 2018). The literature generally recognizes the importance of technologies as key enablers of the circular economy (Kristoffersen et al., 2020). Thus, it is observed that the sample of industries in this research that use monitoring systems have process innovation.

The fourth question addresses the use of automation processes for activity development, a fact that, according to Lima et al. (2017), generates positive results for organizations that adopt it. Amaral (2018) states that companies increasingly seek to automate their processes to boost their results. However, according to Gupta and Barua (2016), resources like automation are found only in large companies. In the textile industry, Dal Forno et al. (2021) demonstrate that process automation increases productivity and reduces costs. In this sense, automation in the textile sector generates process innovation by reducing production time and producing more precise products according to their production specifications.

The fifth question concerns planning the production process only on demand, avoiding the generation of products in stock. Production results on demand align with what is advocated by Ceptureanu et al. (2018), who emphasize optimized production with evidence of waste reduction before and after production. Zhang et al. (2017) highlight the success of companies that work with minimal stock and can quickly meet market needs.

After analyzing how circular economy practices affect process innovation, the direct relationship of the circular economy on process innovation is examined, as represented in **Figure 2.**

Figure 2 – Direct relationship of the circular economy in process innovation



Source: Created by authors

The direct relationship between the constructs of the circular economy and process innovation was measured using the structural equation modeling analysis method. The results are presented in **Table 6.**

Table 6 – Structural model test

Independent Variable	Dependent Variable	Regression Weight (β)	Standard Erro	*t-value*	*p-value*	Endo	R²
Circular Economy	Process Innovation	0.456	0.268	2.948	0.003	0.456	0,208

Source: Research data (2022)

From Table 6, it is possible to identify that the direct relationship between the circular economy and process innovation is 20.8%. That is, the circular economy alone can explain 20.8% of process innovation. Additionally, it has significance greater than 95%, presenting a p-value < 0.05 and a regression weight of β = 0.456, considering the dependent variable process innovation.

The results corroborate the findings of Huynh (2022), where circular models in the fashion industry are related to innovations. Similarly, Zheng et al. (2013) found that social, governmental, and customer pressure positively influences the relationship between the circular economy and process innovation, as well as technological innovation. Thus, circular business models encourage innovation in practices and the creation of strategies to diversify alternatives to create business value (Nussholz, 2020).

The transition to business models where the created value is associated with the circular economy and recovery practices undergo incremental, disruptive, or radical changes that lead to the transformation of business logic (Jabbour et al., 2020), increasing profitability, improving resource utilization, and reducing waste generation (EMF, 2015).

CONCLUSION

This study aimed to evaluate the relationship between circular economy practices and process innovation. For this purpose, an adapted questionnaire was used to measure process innovation, and another was developed to measure the circular economy.

From the perspective of the circular economy, using the ReSOLVE model—which assesses a company's capacity to Share, Regenerate, Optimize, Loop, Virtualize, and Exchange—companies can verify how circular their processes are (EMF, 2015). Process innovation is the implementation of a new or significantly improved production or distribution method (OECD, 2005). Therefore, circular processes are fundamental for improving corporate performance as well as increasing innovation (EMF, 2015; Linder & Williander, 2017; Lacy et al., 2020).

To achieve the general objective of this study, the relationship between circular economy practices and process innovation was statistically verified. Considering the constructs individually, it was observed that the dimensions "Exchange" and "Optimize" positively influence process innovation. That is, companies that adopted practices related to the "Exchange" and "Optimize" constructs obtained positive organizational results concerning process innovation.

Subsequently, the direct relationship between the circular economy and process innovation was analyzed. By evaluating all circular economy practices directly—that is, not separating by constructs—it was concluded that the circular economy positively influences process innovation. These results are directly linked to the practices of optimizing and exchanging, which have a high degree of influence on process innovation.

The theoretical contribution of this study can be seen in the development and psychometric validation of the questions in the ReSOLVE circular economy model, carried out through the application of the Q-sort method. It was found that the adapted model validated the research construct. Thus, textile companies can verify the levels of implementation of their circular economy practices, observed to be in the initial phase (Rizzi, 2023), with little quantitative attention in this regard (De Angelis, 2021). There is little focus on how to evaluate the performance of applying circular practices (De Angelis, 2021) and their performance concerning innovation (Lacy et al., 2020).

For the social context, considering the negative impact of waste generation by the industry (Shirvanimoghaddam et al., 2020; Saha, Dey & Papagiannaki, 2021), this study contributes empirical evidence that the circular economy practices of the ReSOLVE model can optimize production and better utilize production resources. Combined with technological development, they guide companies toward better results in process innovation in the textile industry.

Regarding managerial contributions, the real evidence of applying the ReSOLVE model is highlighted, which mapped the level of implementation of circular practices of the studied companies. It also provided evidence regarding the level of implementation of process innovation and the cause-and-effect relationship between the circular economy and process innovation.

Therefore, companies need to be aware that circular practices are important for achieving positive results in process innovation. For managers who wish to increase the speed of the production process, reduce waste in the production process, and reduce costs, it is recommended to invest primarily in practices related to optimization.

The limitations of this study include: (a) the use of a non-probabilistic sample, making it unfeasible to generalize the results; (b) the sample's concentration in the Itajaí Valley, with little or no feedback from other regions; (c) practices related to the "Share" construct are not applied by a large part of the sample; (d) only process innovation was addressed. An approach covering all forms of innovation could yield more assertive results.

For future studies, in addition to what was mentioned earlier, it is suggested to replicate or expand the sample size in other geographical regions, as well as apply it to other business segments. It is also recommended to evaluate the circular economy in innovation, moderated by the organizational life cycle. The organizational life cycle can show in which phase companies are failing to implement circular economy practices.

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2. Development of hypotheses or research questions (empirical studies)	√		
3. Development of theoretical propositions (theoretical work)	√	√	
4. Theoretical foundation / Literature review	√	√	
5. Definition of methodological procedures	√		√
6. Data collection	√	√	
7. Statistical analysis	√		√
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9. Critical revision of the manuscript			√
10. Manuscript writing	√	√	
11. Other (please specify)			

Conflict of Interest

The authors have stated that there is no conflict of interest.

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Edited by

Jordana Marques Kneipp