ALCANCE

THE INFLUENCE OF INNOVATION HELICES ON ECO-INNOVATION IN THE SEARCH FOR SUSTAINABLE DEVELOPMENT: A SURVEY IN SOUTHERN BRAZIL

A INFLUÊNCIA SDA HÉLICES DE INOVAÇÃO SOBRE A ECOINOVAÇÃO NA BUSCA DO DESENVOLVIMENTO SUSTENTÁVEL: UMA *SURVEY* NO SUL DO BRASIL

LA INFLUENCIA DE LOS PROPULSORES DE LA INNOVACIÓN EN LA ECOINOVACIÓN EN LA BÚSQUEDA DEL DESARROLLO SOSTENIBLE: UNA ENCUESTA EN EL SUR DE BRASIL

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ABSTRACT

Objective: This study aims to analyze the influence of holistic innovation helices on eco-innovation, as well as the consequent environmental practices, cleaner production, social actions, sustainable development, and regional development, through the perception of 2338 participants from southern Brazil, evidenced by six research hypotheses.
Design/methodology/approach: The methodology used was a quantitative and descriptive study, through the application of a survey with respondents from the Brazilian states of Paraná, Santa Catarina, and Rio Grande do Sul. For the data analysis, Exploratory Factor Analysis, Confirmatory Factor Analysis, and Structural Equation Modeling were used.
Results: The hypothesis tests indicate that the relationships between holistic innovation helix and eco-innovation (H1), eco-innovation and environmental practices (H2), eco-innovation and social actions (H4) and eco-innovation and regional development (H6) are considered to be of high intensity (>0.5), the relationship between eco-innovation and cleaner production (H3) of moderate intensity (>0.3 and <0.5). However, the relationship of eco-innovation and sustainable development (H5) is of low intensity (<0.3). The six research hypotheses were confirmed.
Originality/value: The main contribution of the study is evidence that eco-innovation is a strategic drive to significantly increase the elements of environmental sustainability, and a central point for actions aimed at environmental practices, social actions and cleaner production, to promote regional development in southern Brazil.

Keywords: Innovation helix. Eco-innovation. Sustainable development.

RESUMO

Objetivo: Este estudo tem como objetivo analisar a influência das hélices holística de inovação sobre a ecoinovação, bem como os consequentes, práticas ambientais, produção mais limpa, social actions, desenvolvimento sustentável e desenvolvimento regional, por meio da percepção de 2.338 participantes do sul do Brasil, evidenciadas por seis hipóteses de pesquisa.
Design / metodologia / abordagem: A metodologia utilizada tratou-se de uma pesquisa quantitativa e descritiva, viabilizada por uma *survey*, a qual foi aplicada a pessoas do Paraná, Santa Catarina e Rio Grande do Sul. Para a análise de dados utilizou-se a Análise Fatorial Exploratória, Análise Fatorial Confirmatória, assim como a Modelagem de Equações Estruturais.
Resultados: Os testes de hipóteses indicam que as relações entre hélice holística de inovação e ecoinovação (H1), ecoinovação e práticas ambientais (H2), ecoinovação e social actions (H4) e ecoinovação e desenvolvimento regional (H6) são considerados de alta intensidade (>0,5), a relação entre ecoinovação e produção mais limpa (H3) é de moderada intensidade (>0,3 e <0,5), entretanto, a relação de ecoinovação e desenvolvimento sustentável (H5) é de baixa intensidade (<0,3), contudo as seis hipóteses da pesquisa foram confirmadas.
Originalidade / valor: A principal contribuição do estudo está evidência que a ecoinovação é um *drive* estratégico para aumentar significativamente os elementos de sustentabilidade ambiental, bem como é o ponto central para as ações que visam as práticas ambientas, social actions e a produção mais limpa que visam o desenvolvimento regional no sul do Brasil.

Palavras-chave: Hélices de inovação. Ecoinovação. Desenvolvimento sustentável.

RESUMEN

Objetivo: Este estudio tiene como objetivo analizar la influencia de las hélices de innovación holística en la eco-innovación, así como las consecuentes, prácticas ambientales, producción más limpia, acciones sociales, desarrollo sostenible y desarrollo regional, a través de la percepción de 2.338 participantes del sur de Brasil, evidenciada por seis hipótesis de investigación.
Diseño / metodología / enfoque: La metodología utilizada fue una investigación cuantitativa y descriptiva, posibilitada por una encuesta, la cual se aplicó a personas de Paraná, Santa Catarina y Rio Grande do Sul. Para el análisis de datos se utilizó Análisis Factorial Exploratorio, Análisis Factorial Modelado confirmatorio y de ecuaciones estructurales.
Resultados: Las pruebas de hipótesis indican que las relaciones entre hélices de innovación holística y eco-innovación (H1), eco-innovación y prácticas ambientales (H2), eco-innovación y acciones sociales (H4) y eco-innovación y desarrollo regional (H6) se consideran de alta intensidad (>0,5), la relación entre eco-innovación y producción más limpia (H3) es de intensidad moderada (> 0.3 y <0.5), sin embargo, la relación de eco-innovación y desarrollo sostenible (H5) es de baja intensidad (<0.3), sin embargo las seis hipótesis de La investigación ha sido confirmada.
Originalidad / valor: La principal contribución del estudio es la evidencia de que la eco-innovación es un impulso estratégico para incrementar significativamente los elementos de sostenibilidad ambiental, además de ser el punto central

de las acciones dirigidas a prácticas ambientales, acciones sociales, producción más limpia orientadas al desarrollo regional en el sur de Brasil.

Palabras clave: Hélices de innovación. Ecoinnovación. Desenvolvimiento sustentable.

1 INTRODUCTION

The multiple innovation helices, such as government, companies, universities, technology parks, spin-offs, incubators, startups, consulting teams, company shareholders, suppliers and customers, which we term the holistic innovation helix, have suffered from regulatory, coercive and social pressures that seek to reduce environmental impacts and preserve the environment. However, these holistic innovation helices (HIH) are paramount for environmental sustainability and regional development.

But according to Severo and Guimarães (2022), HIH have suffered normative, coercive and social pressures, which are important for the preservation of the environment and natural resources, through their stakeholders. Coherently, HIH are essential, as the government is responsible for public policies, companies, technology parks, spin-offs, incubators and startups for innovations and jobs in the market. Universities, meanwhile, qualify the students who will become the professionals working in these HIH. Therefore, these different HIHs also aim at regional and national development, as well as the competitiveness of organizations.

In this scenario, several environmental problems require new innovative solutions (Brem and Radziwon, 2017; Marín-Vinuesa et al., 2018; Greaker et al., 2020). However, in the development of innovation, it is necessary to incorporate environmental sustainability, to become an eco-innovation (EI), i.e., a sustainable innovation, aimed at maintaining the natural resources, quality of life, competitiveness, and organizational performance.

EI provides extensive contributions to achieving long-term sustainability outcomes. This requires holistic changes around business processes (Severo et al., 2020). In this scenario, EI presents different expressions, all of which are linked to the same approach or subject, e.g. green innovations, sustainable innovations, ecological innovations or environmental innovations (Chen et al., 2018; Wang et al., 2022; Bag et al., 2022; Bag et al., 2018; Wang et al., 2022; Bag et al. al., 2022: Chien et al., 2022), that is, the innovation that contributes to environmental sustainability.

According to Yang et al (2022), EI is a driving force for high-quality economic development, which can promote economic growth and, at the same time, ensure ecological benefits. A study by Wu et al. (2022), carried out in China, highlights that a new green credit policy, through financial institutions, is an exogenous engine to improve companies' EI. Thus, both government and financial institutions can foster the development of EI in the other holistic helices (companies, universities, technology parks, spin-offs, incubators, startups, and suppliers).

There is a theoretical gap, in the literature, regarding the collaboration between HIH with EI, which according to Guerrero and Urbano (2017), is inherent in emerging economies, as the benefits of innovation helices are still insignificant. Therefore, further studies are needed, in order to better understand the how these agents influence innovations. Accordingly, environmental practices (EP) and the cleaner production (CP) methodology can be used in EI to correctly segregate generated waste and reduce the consumption of natural resources.

According to Alos-Simo et al. (2020), the literature confirms that every sector is affected by specific technologies, which determine innovations in goods and services, although these technological differences remain ambiguous in the context of EI. Furthermore, the relationship between EI, CP, and different performance measures is not entirely clear. For Latupeirissa and Adhariani (2020), EI is an evolving area of research that may have practical implications for CP; although there has been extensive research aimed at identifying the economic consequences of EI, there are still many questions about its impact in the context of developing countries.

According to Kumar and Anbanandam (2019), although researchers and practitioners have focused their attention on the economic and environmental dimensions of sustainability, less attention has been given to the social dimension of sustainability, particularly in developing countries. To this end, social actions (SA) focused on innovation have driven organizational change and encouraged holistic strategic management, addressing sustainability challenges (Roome, 2011).

In light of the above, the research question of this study is: what is the influence of the holistic innovation helix (HIH) on eco-innovation (EI), as well as the consequent environmental practices (EP), cleaner production (CP), social actions (SA), sustainable development (SD) and regional development (RD)? This study aims to analyze the influence of the holistic innovation helix (HIH) on eco-innovation (EI), as well as the consequent environmental practices (EP), cleaner production (CP), social actions (SA), sustainable development (SD) and regional development (RD), through the perception of 2338 participants from southern Brazil.

2 THEORETICAL BACKGROUND

2.1 Holistic innovation helices and eco-innovation

In relation to innovative helices, Etzkowitz and Leydesdorff (1995) and Luengo-Valderrey et al. (2020) highlight the triple helix, in which innovation occurs at the intersection of three institutional spaces: companies, government, and educational institutions. In this scenario, the triple helix aims to develop innovation at the intersection of these three institutional spaces, which becomes a drive to promote innovation and economic development of organizations and countries (Etzkowitz and Leydesdorff, 1995; Etzkowitz and Zhou, 2017). It also helps transform their actions and practices towards the development and strengthening of national innovation and entrepreneurial ecosystems (Etzkowitz and Leydesdorff, 2000).

According to Cai and Etzkowitz (2020), the explanatory power of the triple helix was strengthened by the integration, into its structure, of several concepts of Social Sciences, such as Schumpeter's organizational entrepreneur, institutional logic, and social networks, as well as academics and professionals from various disciplinary and interdisciplinary fields of research, including artificial intelligence, political theory, sociology, professional ethics, higher education, regional geography, and organizational behavior. The integration of all these elements in the triple helix studies has led to new directions in research on the triple helix.

According to Zhou and Etzkowitz (2021), the debate on the expansion of the triple helix model has focused on whether the fourth and fifth helices can improve or disrupt the triple helix model. While a four-stakeholder system is far from satisfactory, an expanded model is needed to incorporate the critical issues of reconciling innovative and sustainable development to meet the related Sustainable Development Goals (SDG) through joint projects that transcend national borders. In this context, a quintuple helix model may be more relevant for national development.

According to Sato (2017) and Severo et al. (2022), an in-depth investigation is needed into how successful cases of innovation were achieved only after the creation of an attractive environment, mainly through the combined efforts of the interaction between the holistic helices, which can influence EI (Severus et al., 2020).

EI that reduces the environmental effect of manufacturing and consumption is seen as a critical component of sustainable development, as well as contributing to a circular economy (Hamam et al., 2022), which is essential for maintaining the natural resources and ensuring its availability for future generations.

2.2 Eco-innovation, environmental practices and cleaner production

According to García-Granero et al. (2018) and García-Sánchez et al. (2020), EI aims at environmental sustainability. In innovative strategies, EI seeks to reduce the environmental impact of products and processes, using new technologies and ways of working that contribute to sustainable development and, at the same time, help to promote the competitiveness of organizations (García-Sánchez et al., 2020).

In this context, in recent years, the topic of EP, through EI, has received increasing attention in academic research (Park et al., 2017; Chen et al., 2017; Cai and Li, 2018; Hojnik et al., 2018; Severo et al., 2018; Wong et al., 2020), whether to raise awareness in society (Park et al., 2017), or through discussions in political circles (Hojnik and Ruzzier, 2016).

According to Chen et al. (2017), in this new era of ecological civilization, EI has a high and distinctive value for contemporary organizations. Hojnik et al. (2018) highlight that EI adoption is on the rise, both among companies and consumers. At an industrial level, the development of EI provides a mechanism for achieving sustainability (López and Montalvo, 2015), and for the consumer, EI is a way of expressing conscious consumption (Severo et al., 2018).

Within the scope of the EP, cleaner production (CP) emerges, in which dynamic capabilities, such as the introduction of environmental management systems (EMS), are closely correlated with investments in CP aimed at reducing the consumption of energy, water, raw materials, and natural resources (Garcia-Quevedo et al., 2022; Chen et al., 2022; Li et al., 2022).

CP is an efficient practice, when used in the production process, for reducing the consumption of inputs and raw materials, optimizing the production process, reducing industrial waste, and ensuring adequate treatment of each type of waste, as well as reducing the costs of disposal and final treatment of the waste generated in the production process (Simsek et al. 2022; Chen et al., 2022).

2.3 Eco-innovation and social actions

EI associated with social actions (SA) is still a recent topic in the scientific literature, as social responsibility is usually focused on the employees and society, or on philanthropy, reputation, and organizational image (Jamali et al., 2015; Scarpellini et al, 2016; Voegtlin and Greenwood, 2016; Gold et al., 2018; López-González et al., 2019). According to Scarpellini et al. (2012), social actions also need to be incorporated into the private sector, particularly in medium and small companies, to meet the needs of society. EI, on the other hand, is concerned with developing innovations aimed at environmental sustainability, which also includes the company's reputation and organizational image (Mady et al., 2022; Zhao et al., 2022).

Wilson (2022) highlights that community oriented SAs should include diverse representatives (youth, women, the elderly, the disabled, and civil society) and not only the views of powerful and influential traditional leaders. This will ensure that the SA benefit different agents, as well as contributing to environmental sustainability (Severo and Guimarães, 2022).

According to Cai and Xu (2022), EI is an imperative way of harmonizing the relationship between environmental protection and economic growth. Thus, technological interventions and EI solutions are needed to deal with the adverse environmental impacts of waste accumulation. Technological EIs rely on the automation of waste segregation, collection, route optimization, and digital applications for creating communication and treatment technologies (Yadav et al., 2022).

Economic globalization, when it does not interact with EI, results in ecological deterioration, but EI provides ecological protection. The development of EI and efficient management practices, such as clean and energy-efficient environmental technologies for long-term ecological sustainability (Ahmad and Wu, 2022), besides decreasing the environmental impact, can also make use of SA for socially vulnerable people, employees, and the community in general (Scarpellini et al., 2016; Bontoux and Bengtsson, 2016).

2.4 Eco-innovation, sustainable development and regional development

EI is an effective way of bringing together new technologies, communication, and environmental sustainability. Xavier et al. (2017) report that several business models have been proposed to help companies achieve a greater understanding of the dynamics of EI, in order to facilitate the integration of sustainable processes and optimize dynamic resources and capabilities. For Bossle et al. (2016) it is important to include all agents in the process of transition to an economy that integrates ecological concepts into innovation and competitiveness strategies, which is the main function of the EI strategy.

According to Arranz et al. (2019), regional interaction and regional characteristics are key elements for the development of EI in companies. Thus, the density of companies in a region, the regional per capita income, and the existence of financing mechanisms are key elements for the development of EI in a company.

Hetman et al. (2019) highlight a new way of looking at the regional development; ways in which the ecology of innovative development should be used for the strategic advantage of a region, and how EI processes can be a catalyst for competitiveness, promoting sustainable development of the regional economy.

EI is an integral part of the business strategy in all developed countries (Malega et al., 2021). However, the development of EI is still complex due to the financing of classic innovations, that is, those aimed only at improving organizational performance. However, there are several successful EI projects, contributing to sustainable development (Dogaru, 2020; Magela et al., 2021) and regional development (Hetman et al., 2019).

3 RESEARCH HYPOTHESES

3.1 Holistic innovation helices and eco-innovation

In the triple helix, each strand relates to the other two, resulting in an overlap of communications, networks, and organizations (Dudin et al., 2015) to face challenges related to creativity and innovation (Thomasson and Kristoferson, 2020). But for Carayannis and Campbell (2009), there is a fourth helix, which is combined with the public perspective, based on media and culture, resulting in an emerging knowledge and innovation ecosystem that is well configured for the knowledge economy and society. According to Carayannis et al. (2017), the fifth helix supports the formation of a win-win situation between ecology, knowledge, and innovation, creating synergies between the economy, society, and democracy, forming a good basis for the sustainable development of territories.

These interactions between HIH, in turn, are key to promoting innovation and economic development of organizations and countries (Guerrero and Urbano, 2017; Etzkowitz and Leydesdorff, 2000; Li et al., 2018; Luengo-Valderrey et al., 2020).

Innovation that takes account of environmental sustainability can be a new frontier for organizational competitiveness (Severo et al., 2018). EI can improve a company's environmental performance and, consequently, have a positive impact on its economic performance (Cai and Li, 2018; You et al., 2019; Latupeirissa and Adhariani, 2020). In this scenario, HIH can foster EI (Carayannis and Campbell, 2010; Gouvea et al., 2013; Luengo-Valderrey et al., 2020). In view of the above, hypothesis H1 was developed.

H1: The holistic innovation helix (HIH) is positively related to eco-innovation (EI).

3.2 Eco-innovation, environmental practices and cleaner production

Globally, EI aims to use EP, as well as the dimensions of sustainable development, integrating the environment, technology, and stakeholders (Pialot and Millet, 2018). Coherently, EPs aim to reduce the use of natural resources, such as materials, energy, water, and land, as well as the release of harmful substances, through the introduction of a new or improved product (good or service), process, organizational change (Cheng and Shiu, 2012; Cheng et al., 2014; Pinto et al. 2018), or market program (Chen et al., 2017), using the CP methodology in the industrial process (Zhang et al., 2018; Severo et al., 2018; Dong et al., 2019).

CP is an environmental methodology created by the United Nations Industrial Development Organization, a specialized agency of the United Nations, which promotes industrial development for the reduction of poverty, through inclusive and environmentally sustainable globalization (De Guimarães et al., 2019).

According to Cong and Shi (2018), CP is a key concept of sustainable development, as well as the continuous application of a preventive and integrated environmental strategy, which emphasizes the importance of the environment and people (Dong et al., 2019). EI consistently uses EP (Park et al., 2017; García-Sánchez et al., 2020), as well as CP methodologies (Zhang et al., 2018; Severo et al., 2018; Alos-Simo et al., 2020). In this context, hypotheses H2 and H3 are presented.

H2: Eco-innovation (EI) is positively related to environmental practices (EP).

H3: Eco-innovation (EI) is positively related to cleaner production (CP).

3.3 Eco-innovation and social actions

The implementation of EI is a goal for organizations to be more sustainable, reduce negative external factors, and meet the ecological requirements of governments and consumer demands for SA (García-Granero et al., 2018). However, for Hojnik and Ruzzier (2016), regulations and market attraction factors are the most critical drivers of EI in companies.

According to Halkos and Skouloudis (2018), recent and drastic socio-economic and political changes, inefficiencies in the public sector, and limited resources due to macroeconomic instability are leading companies to actively seek to mitigate environmental and social pressures, and to focus on problems beyond merely managing external factors, creating value for the common good. According to Kumar and Anbanandam (2019), a sustainable business organization needs to consider the importance of economic, environmental, and social sustainability.

In this scenario, EI can make use of SA as a catalyst to address urgent social problems which, if properly managed, can be transformed into large-scale social opportunities (Rake and Grayson, 2009; Scarpellini et al., 2012; Scarpellini et al., 2016; Bontoux and Bengtsson, 2016), as well as leading to the implementation of EI with of high added value for social responsibility (Topleva and Prokopov, 2020). In light of the above, hypothesis H4 is presented.

H4: Eco-innovation (EI) is positively related to social actions (SA).

3.4 Eco-innovation, sustainable development and regional development

Tamayo-Orbegozo et al. (2017) highlight that EI attracts interest among companies, governments, and researchers as a means of achieving a higher degree of SD. Therefore, EI significantly contributes to the development of the region sustainably, as innovation can be directed to the SD to preserve natural resources for future generations (Severo et al., 2018). Thus, EI is a tool that demonstrates the evolution of the environmental behavior of organizations, seeking to reduce environmental impacts, improve environmental performance, and provide SD, and enabling companies to gain competitive advantage (Peiró-Signes and Segarra-Oña, 2018; Kiefer et al., 2018; Salim et al., 2019).

According to Cancino et al. (2018), there is a need to manage technological innovations for sustainable growth from a systematic perspective. Tamayo-Orbegozo et al. (2017) highlight that EI is an emerging topic among companies, universities, and governments, as it is an efficient way to achieve a higher degree of SD. Sustainable innovations can influence SD, through the creation of a new generation of sustainable products, services, and technologies capable of stimulating the world economy and RD (Gouvea et al, 2013; De Guimarães et al., 2018).

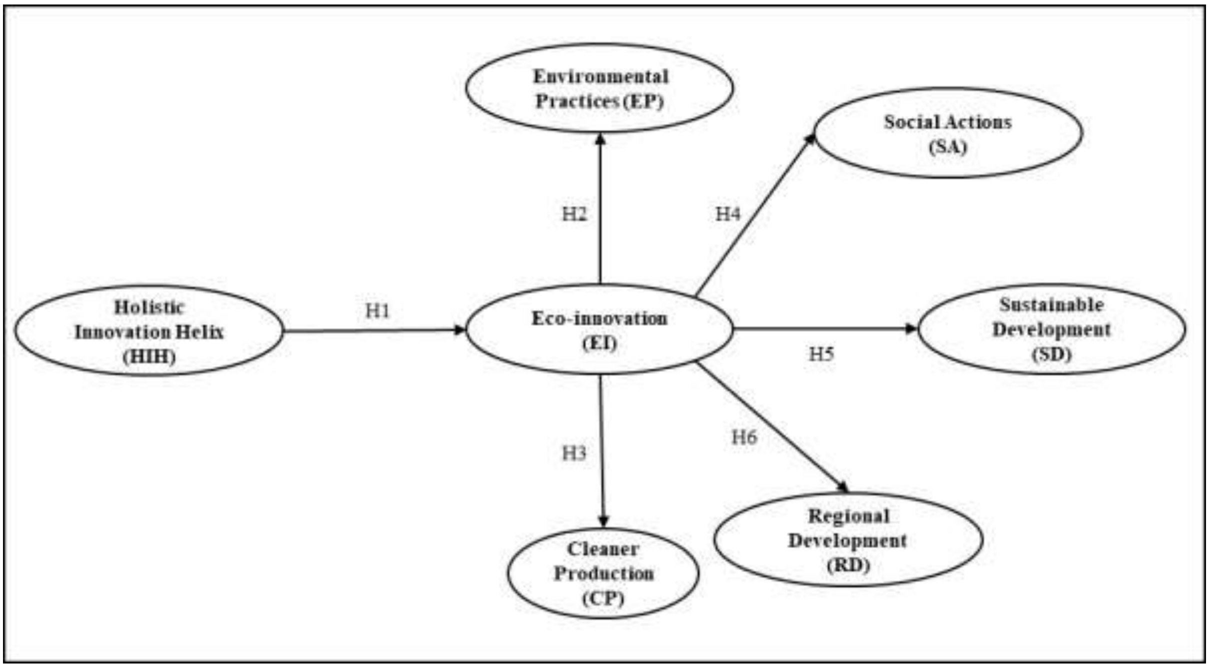
Notably, the sharing of common resources, with the objective of establishing urban and regional EI, requires sustainable partnerships and cooperation strategies between the different stakeholders, aimed at SD and RD (Aldieri et al., 2019; Amara and Chen, 2020). This development can meet the needs of current generations, without compromising the supply capacity of future generations (Severo et al., 2018). Based on the precepts of EI, SD, and RD, and the interaction between these constructs, hypotheses H5 and H6 are proposed.

H5: Eco-innovation (EI) is positively related to sustainable development (SD).

H6: Eco-innovation (EI) is positively related to regional development (RD).

Based on the research hypotheses, the Theoretical Model was developed (Figure 1), composed of the six hypotheses, which expresses the theoretical framework for analyzing the research data, considering the relationships of influence between the constructs.

Figure 1.
Theoretical models



Source: Prepared by the authors (2020).

4 METHOD

The research is classified as quantitative and descriptive. It involved a survey with 2338 participants living in the southern Brazilian states of Paraná, Santa Catarina, and Rio Grande Sul. According to Hair Jr. et al. (2013), quantitative research presents greater benefits, as it allows the measurement of different relationships for the positive confirmation of results, through statistical procedures. According to Vergara (2010), descriptive researc aims to determine the population or phenomenon, correlate its variables, and identify and define its nature.

It is worth noting that the sample is classified as non-probabilistic, by convenience (Hair Jr. et al., 2013). The data collection took place between December 12, 2019, and January 27, 2020, through a questionnaire applied using the Snowball technique. First, the researchers sent the electronic questionnaire (Google Forms) to contacts and networks. social media (email, Facebook, and WhatsApp). They then replicated the research with other people, because according to Lee and Spratling (2019), a snowball sampling effect occurs, through the use of social media. The questionnaire contained four questions on the respondents' profiles and 33 statements (Table 1), with responses to be given on a 5-point Likert scale: 1 Totally Disagree; 2 Partially Disagree; 3 Neither Agree Nor Disagree; 4 Partially Agree; and, 5 Strongly Agree. The questionnaire was previously validated by three doctoral experts in the areas of innovation, environmental sustainability, and regional development.

Initially, a pre-test was applied to 32 respondents, to check their understanding of the questions and the length of time taken to complete the questionnaire. The responses of the pre-test were then incorporated into the research sample. We obtained a response rate of 70.8 respondents per question, which exceeds the 10 respondents stipulated by Hair Jr. et al. (2013).

To characterize the respondents' profiles, the following questions were asked: i) respondent's age: the respondents were classified into different generations, based on studies by Strauss and Howe (1991): those born before 1965 (Baby boomers); those born between 1965 and 1981: Generation X, and those born after 1981: Generation Y; ii) Sex: female, male or other; iii) Level of Education; iv) Job and position in the company; and v) Region of residence.

There is an evident lack of validated scales to analyze the combined influence of HIH on EI, and the consequent EP, CP, SA, SD, and RD. Therefore, the questionnaire (Table 1) was developed based on the following studies: i) Holistic innovation helix (HIH): adapted from the theoretical assumptions of Etzkowitz and Leydesdorff (1995), Etzkowitz and Leydesdorff (2000), Gouvea et al. (2013), Grundel and Dahlström (2016), Guerrero and Urbano (2017) and Chen et al. (2018); ii) Eco-innovation (EI): based on the study by Severo et al. (2018); iii) Environmental Practices (EP): adapted from studies by García-Granero et al. (2018), Pinto et al. (2018) and Severo et al. (2018); iv) Cleaner Production (CP): adapted from the assumptions of Cong and Shi (2018) and the research by Severo et al. (2018) and; v) Social Actions(SA): adapted from research by Voegtlin and Greenwood (2016), Tamayo-Orbegozo et al. (2017) and Halkos and Skouloudis (2018); vi) Sustainable Development (SD): adapted from the study by Severo et al. (2018); and, vii) Regional Development (RD): adapted from research by Bossle et al. (2016) and Liu and Huang (2018).

For the data analysis, data normality and reliability were verified, then Exploratory Factor Analysis (EFA) was performed using Varimax Rotation, and Confirmatory Factor Analysis (CFA) using SPSS® software (v. 21).

The Structural Equation Modeling (SEM) method was applied using the software program AMOS® (v.21). To operationalize the SEM methodology, the steps suggested by Byrne (2010), and Kline (2011) and Hair Jr. et al were adopted. (2013). These authors consider the need to define the theoretical model, build the significance level $p<0.001$ (causal relationships); define the type of input matrix and estimation of the theoretical model, evaluate the structural model, evaluate the goodness of fit of the model and, if necessary, adjust and modify the model.

The data debugging followed certain steps: i) removing cases of non-responses greater than 10%; ii) excluding cases with responses in a single alternative of the 5-point Likert scale; iii) cases of extreme scores, with analysis of univariate and multivariate outliers, following the recommendations of Kline (2011) and Hair Jr. et al (2013), in which the calculation of Z scores (between -3 and +3) for each variable was used; and iv) cases of Kurtosis, in which each observable variable was evaluated using the Mardia's coefficient (Mardia, 1971; Bentler, 1990); v) use of Pearson's Skewness coefficient; and vi) application of the Kolmogorov-Smirnov and Shapiro-Wilk tests to verify the normality of the data. The latter tests presented significant results, indicating normality of the data. Of the 2364 questionnaires initially collected, 26 were excluded, as there was only one alternative response (univariate outliers). There were no cases of questionnaires with missing responses, leaving a final sample of 2338 valid cases, which is higher than that recommended by Kline (2011) and Hair Jr. et al. (2013) who suggest between 200 and 400 respondents for the use of SEM.

Regarding the tests performed, for all variables (33 observable variables) the normality, reliability, and internal consistency of the data were verified through Cronbach's Alpha, Kaiser-Meyer-Olkin (KMO), Bartlett's sphericity tests and the total explained variance (Hair Jr. et al., 2013), according to Table 1 and 2.

5 RESULTS

The final sample consists of 2338 valid cases, distributed as follows: i) Sex: 51.8% male; 48.2% female; iii) Education: 67.3% were studying or had a degree; 14.3% were studying or had a specialization (Postgraduate) degree; 12.6% were attending or had completed high school; 5.8% were currently studying or had a post-graduate degree at master's, doctoral or post-doctoral level; iv) 91.6% were employed: 31.3% assistant/technician/analyst, 9.9% managers, 13.3% teachers, and 37% other professional activities; only 8.5% were not in employment, but were studying. Regarding the region, 56% of respondents lived in RS, 30% in SC, and 14% in PR.

After the tests of normality, reliability, and internal consistency of the data for all the variables, the EFA technique (Table 1) was applied through the Varimax Rotation - analysis between blocks, according to the following parameters Hair Jr. et al (2013): i) verify the combination of observable variables in the formation of constructs; ii) verify the Factorial Loads of each variable (=or>0.5); iii) verify the percentage of explanation of the variance of the set of variables (>60%); iv) check the communality (=or>0.5); v) check the simple reliability: Cronbach's Alpha (>0.7); vi) Bartlett's sphericity tests (significant p<0.001); and, vi) Kaiser-Meyer-Olkin (KMO) calculation (>0.7). All the statistical tests showed significant values (Table 1), i.e., they were within the parameters suggested by Hair Jr. et al. (2013).

Table 1 presents the observable variables, the respective research constructs, the statements that were on a 5-point Likert scale, Factorial Loads, and communality.

Table 1.
Observable variables and constructs

Constructs	Factorial Loads	Communality
Holistic Innovation Helices (HIH)		
HIH1) I consider that the interactions between government, universities, technology parks, business incubators, spin-offs, startups, companies, customers, and suppliers characterize the holistic innovation helices and promote eco-innovation..	0.734	0.670
HIH2) I observe, in the regional context, the positive impacts caused by the holistic innovation helices	0.595	0.607
HIH3) I consider the holistic innovation helix to be the key to the development of new environmentally friendly products, processes, and services.	0.763	0.722
HIH4) I consider the relationship of holistic innovation helix to be a decisive factor for economic, social, and environmental development.	0.698	0.787
HIH5) Government policies are fundamental for the interaction between the agents of the holistic innovation helix.	0.895	0.923
Cronbach's Alpha: 0.849; KMO 0.685; Composite Reliability: 0.918; Total variance explained: 64.7%		
Eco-innovation (EI)		
EI1) Eco-innovation fosters a new perspective on the relationship between innovation and the environment.	0.581	0.576
EI2) Eco-innovation provides value to the business/product/service.	0.717	0.695
EI3) Eco-innovation encourages the use of environmental practices in companies.	0.576	0.629
EI4) Eco-innovation leads to reduced environmental impact.	0.680	0.700
EI5) Eco-innovation provides contributions to achieving long-term sustainability outcomes.	0.530	0.618
Cronbach's Alpha: 0.837; KMO 0.775; Composite Reliability: 0.900; Total variance explained: 61.1%		
Environmental Practices (EP)		
EP1) Environmental practices reduce the use of natural resources, materials, energy, water, land, and the release of harmful substances.	0.950	0.979
EP2) The implementation of environmental practices associated with eco-innovation makes organizations more sustainable.	0.946	0.971
EP3) At home, I separate recyclable and electronic waste.	0.928	0.878
EP4) The use of environmental practices influences my environmental awareness.	0.671	0.683

Cronbach's Alpha: 0.927; KMO 0.715; Composite Reliability: 0.975; Total variance explained: 85.7%		
Cleaner Production (CP)		
CP1) I prefer to buy products or services from companies that seek to reduce the consumption of raw materials, water and energy in their processes.	0.738	0.645
CP2) Whenever possible, I try to acquire products and services from companies that work on improvements in the production process that reduce waste generation.	0.686	0.555
CP3) I consider it very important for companies to use new practices aimed at cleaner production.	0.882	0.792
CP4) I believe that the use of cleaner production methodologies is positively linked to the company's image among stakeholders.	0.812	0.716
Cronbach's Alpha: 0.930; KMO 0.793; Composite Reliability: 0.897; Total variance explained: 66.9%		
Social Actions (SA)		
SA1) Social actions developed by companies help socially vulnerable people.	0.734	0.776
SA2) Social actions developed by companies influence the reduction of poverty and social inequality.	0.783	0.705
SA3) Social actions developed by companies encourage commitment to children's future.	0.648	0.690
SA4) The social actions of the companies encourage care with health, safety, and working conditions.	0.755	0.729
SA5) The social actions of companies go beyond employees and society, aiming at philanthropy, reputation, and organizational image.	0.650	0.534
SA6) Regional/global social problems influence my social responsibility actions.	0.883	0.940
Cronbach's Alpha: 0.906; KMO 0.774; Composite Reliability: 0.950; Total variance explained: 69.7%		
Sustainable Development (SD)		
SD1) My consumption of food/products/services is conscious with a view to sustainable development.	0.539	0.559
SD2) I use collective vehicles (buses, trains, subways, bicycles, others) with a view to sustainable development.	0.911	0.890
SD3) I buy green products with sustainable development in mind.	0.821	0.719
SD4) I use natural resources (water, land, sun, winds, others) with a view to sustainable development.	0.688	0.569
Cronbach's Alpha: 0.773; KMO 0.538; Composite Reliability: 0.881; Total variance explained: 63.1%		
Regional Development (RD)		
RD1) The new business models (Cooperatives, Networks, Associations, Individual Microentrepreneurs, others) of companies promote regional development.	0.582	0.587
RD2) The economy that integrates ecological concepts in innovation and competitiveness strategies promotes regional development.	0.590	0.628
RD3) Regional development created new sources of income in the region.	0.696	0.757
RD4) Regional development contributes to increasing jobs in the region.	0.749	0.722
RD5) I noticed that eco-innovation promotes regional development.	0.629	0.772
Cronbach's Alpha: 0.881; KMO 0.808; Composite Reliability: 0.927; Total variance explained: 67.9%		

Source: Prepared by the authors (2020).

In view of the above, the statistical tests for all observable variables showed significant values (Table 2), i.e., they were within the parameters suggested by Hair Jr. et al. (2013), as well as the Total variance explained is 71.9%. Table 2 presents the tests: Cronbach's Alpha; KMO; Bartlett's sphericity tests; Chi-square; DF; Sig.; and, Total explained variance.

Table 2.
Tests for all variables

Cronbach's Alpha	0.931
Kaiser-Meyer-Olkin (KMO)	0.818
Bartlett's sphericity tests Chi-square DF Sig.	 73716.4164820717 528 0.000
Total variance explained	71.9%

Source: Data from the survey (2020).

In the process of evaluating the normality of the simple reliability of the data, Bartlett's sphericity tests were measured, showing significant values (p<0.001) in the constructs and the set of all variables (Tables 1 and 2), identifying the normality of the data, therefore, the data had a normal distribution. This result was confirmed by the Mardia's coefficient test (>5), as well as the Pearson's Skewness coefficient (close to zero) (Kline, 2011; Hair Jr. et al., 2013).

Table 2 shows Cronbach's Alpha values (0.931) for all variables, which were above the recommendations (>0.7) of Hair Jr. et al. (2013). The mean and standard deviation of the observable variables demonstrate that the respondents agree with the statements, as the mean responses were greater than 3.6 and the mean standard deviation of the responses was close to 1.

The validation of the scale, observable variables, and constructs occurred with the application of the EFA and Composite Reliability, following the precepts of Fornell and Larcker (1981), Marôco (2010), and Hair Jr. et al. (2013). In calculating the EFA (Table 1), principal components analysis was used, using the Varimax Rotation, which grouped the observable variables into the seven constructs (Holistic Innovation Helix – HIH, Eco-innovation – EI, Environmental Practices – EP, Cleaner Production – CP, Social Actions – SA, Sustainable Development – SD and Regional Development – RD), with 71.91% of accumulated explained Variation of the data of all observable variables. As shown in Table 1, the explained variance of each construct was greater than 61%, which is higher than that recommended (>60%) by Hair Jr. et al. (2013).

The KMO values (Table 1) are higher (>0.5), indicating the adequacy of the factor analysis model, through the test of the general consistency of the data. Therefore, the research data show suitability and feasibility for the application of EFA. Factorial Loads and communality (Table 1) resulted in values higher than recommended (≥0.5). These results indicate that observable variables contribute to construct formation and are closely correlated with each other.

The calculation of the Composite Reliability of the set of all variables was 0.989, therefore the AVE of 0.730, in relation to the Composite Reliability of each construct (Table 1) was higher than those recommended (>0.7) by Hair Jr. et al. (2013).

Pearson's Correlation analysis did not identify high correlations (greater than 0.8) between the variables, indicating that Multicollinearity was not identified, as recommended by Hair Jr. et al. (2013).

The Average Variance Extracted (AVE) analysis was also performed, which explains the total variance of each observable variable. It is used to evaluate the construct (Marôco, 2010), through the Composite Reliability, where it is possible to evaluate the Convergent Validity (CV) (>0.5) and Discriminant Validity (DV), which is expected to be less than CV. Table 3 shows the AVE for each Construct investigated.

Table 3 shows that in all constructs, the DV is smaller than the CV (HIH 0.700[a], EI 0.645[a], EP 0.908[a], CP 0.689[a], SA 0.760[a], SD 0.675[a] and RD 0.721[a].

Table 3.
Average variance extracted (AVE)

Constructs	HIH	EI	EP	CP	SA	SD	RD
Holistic Innovation Helix (HIH)	0.700[a]						
Eco-innovation (EI)	0.472[b]	0.645[a]					
Environmental Practices (EP)	0.150[b]	0.380[b]	0.908[a]				
Cleaner Production (CP)	0.277[b]	0.563[b]	0.201[b]	0.689[a]			
Social Actions (SA)	0.220[b]	0.491[b]	0.348[b]	0.160[b]	0.760[a]		
Sustainable Development (SD)	0.086[b]	0.251[b]	0.063[b]	0.103[b]	0.160[b]	0.675[a]	
Regional Development (RD)	0.443[b]	0.721[b]	0.481[b]	0.311[b]	0.647[b]	0.217[b]	0.721[a]

[a]Convergent Validity (CV) and [b]Discriminant Validity (DV)
Source: Data from the survey (2020).

Figure 2 presents the measurement model and the structural model, with the SEM results. To evaluate the influence relationships between the constructs, the hypothesis tests were carried out, resulting in the values of Unstandardized Estimates (UE) and Standardized Estimates (SE) expressed in Table 4. The results of UE and SE are statistically significant ($p<0.001$). The SE values indicate that the relationships between HIH→EI (H1), EI→EP (H2), EI→SA (H4), and EI→RD (H6) are considered to be of high intensity (>0.5), and the relationship between EI→CP (H3) is of moderate intensity (>0.3 and <0.5), however, the relationship of EI→SD (H5) is important, but of low intensity (<0.3). Based on the above, all six research hypotheses were confirmed.

Table 4.
Hypothesis Tests

	Constructs			Standardized Estimate (SE)	Unstandardized Estimate (UE)	p
H1	Holistic Innovation Helix (HIH)	→	Eco-innovation (EI)	0.503	0.394	***
H2	Eco-innovation (EI)	→	Environmental Practices (EP)	0.524	0.449	***
H3	Eco-innovation (EI)	→	Cleaner Production (CP)	0.441	0.766	***
H4	Eco-innovation (EI)	→	Social Actions(SA)	0.566	0.766	***
H5	Eco-innovation (EI)	→	Sustainable Development (SD)	0.270	0.238	***
H6	Eco-innovation (EI)	→	Regional Development (RD)	0.789	0.819	***

*** Significance level p<0,001
Source: Data from the survey (2020).

To assess the quality of the integrated model, the model fit indices were verified based on studies by Bentler (1990) and Hair Jr. et al. (2013). Table 5 shows the results of the calculation of all the observable variables, in which the values of AVE, Composite Reliability, and KMO are considered satisfactory. However, the specific indices of adjustment of the structural model ($\chi2$/DF, RMSEA, NFI, IFI, TLI, CFI, GFI, AGFI) were outside the recommended parameters ($\chi2/DF\leq5$; RMSEA between 0.05 and 0.08; NFI GFI and AGFI ≥0.90; IFI, TLI and CFI values close to 1.0). These results do not invalidate the confirmation of the research hypotheses; they only indicate that the model can be improved, with the inclusion or exclusion of observable variables, as well as with the possibility of inserting into the structural model the possible correlations between the observable variables and between the constructs. This finding is suggested for future studies. Table 5 indicates the Model Fit Indices (AVE*, Composite Reliability *, KMO*, $\chi2$/DF, RMSEA, NFI, IFI, TLI, CFI, GFI, and AGFI). However, it is worth mentioning that the information in this research is merely a cross-section, and that the evidence may be indicative of a cause, with the results and inferences being restricted to the research sample, which is 2338 participants from the south of Brazil.

Table 5.
Model Fit Indices

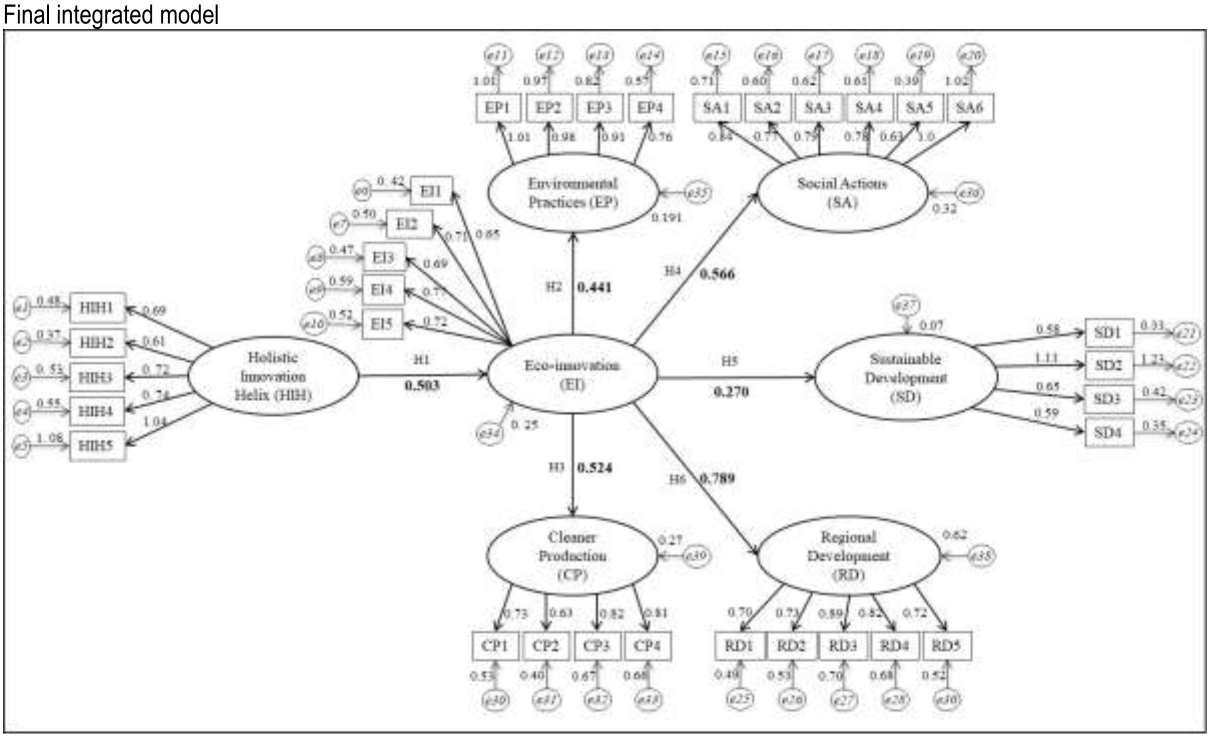
AVE*	Composite Reliability *	KMO*	X^2/DF	RMSEA	NFI	IFI	TLI	CFI	GFI	AGFI
0.730	0.989	0.818	37.1	0.124	0.755	0.761	0.741	0.760	0.699	0.655

* Significance level p<0.001
Source: Data from the survey (2020).

The data collection through social networks influenced the high rate of respondents of Generation Y (76.7%), with Generation X composed of (20.5%) and Baby Boomers (2.8). Most of the respondents were studying or had completed higher education, and many had a postgraduate degree, with specialization at master's, doctoral or postdoctoral levels (87.5%). This profile of the respondents allows for more assertive answers, as their training enables them to understand the statements presented in the survey.

Normality, reliability (simple and composite) tests, variance tests, and EFA validated the scale and constructs. Therefore, the questionnaire was statistically validated through the developed Framework. The results of the research, in relation to the measurement model (observable variables), allow us to affirm that the scale developed in this research is viable to measure the composition of the constructs. This questionnaire can, therefore, be applied in other contexts.

Figure 2.
Final integrated model



Source: Prepared by the authors (2020).

6 DISCUSSION

The high values for Factorial Load, communality, and AVE indicate that the constructs are consistent in their measurements and that there is a close internal correlation between the observable variables in the formation of the construct. This demonstrates the importance of the elements that make up each construct. For example, to evaluate EI, it is essential to address the issues that involve the guidelines for sustainable business, including the relationship between innovation and the environment, according to the precepts of López and Montalvo (2015) and García-Sánchez et al. (2020), as well as adding value to the business/product/service, according to research by Pialot and Millet (2018), which add value to the environment, technology and stakeholders.

The hypothesis tests found significant relationships between the studied constructs. The research proved that HIH is an important antecedent and directly influences EI (H1) (HIH→EI), with a high intensity (SE=0.503). This corroborates the studies by Dudin et al. (2015), Li et al. (2018), and Luengo-Valderrey et al. (2020), which states that active interactions in research and development (R&D) networks of institutional actors in innovation helices, such as university-industry-government, can improve countries' innovative capabilities. The results of this research also corroborate the argument of Liu and Huang (2018), that universities have a fundamental role in the relations of innovation helices, as they are training the citizens who will manage organizations.

The hypothesis test (EI→EP) of H2 showed a moderate influence (SE=0.441), which is effective for reducing the use of natural resources, such as materials, energy, and water, reducing atmospheric pollution and environmental impacts. This corroborates the research by Cheng and Shiu (2012), Cheng et al. (2014) and Pinto et al. (2018). According to García-Sánchez et al. (2020), EI seeks to reduce the environmental impact of products and processes, using new technologies and work that contribute to sustainable development, as well as increasing organizational competitiveness.

Regarding H3, the hypothesis test (EI→CP) had a high influence (SE=0.524), they emphasize that the EI when using CP will have efficiency in its production process, because according to the study by Cong and Shi (2018), CP is a methodology for sustainable development, as well as the continuous application of a preventive and integrated environmental strategy to the production process, with an emphasis on reducing the consumption of raw materials and inputs, as well as the generation of residues (Severo et al., 2018; Zhang et al., 2018; Alos-Simo et al., 2020).

In this scenario, the hypothesis test of H4 (EI→SA) also indicated high intensity (SE=0.566), and global influence of social responsibility actions, which is in line with research by Halkos and Skouloudis (2018), as socioeconomic and political changes cause companies to actively engage in mitigating social pressures, problems beyond the mere management of external factors, creating value for the common good (Bontoux and Bengtsson, 2016).

However, the hypothesis test for H5 (EI→SD), despite being significant, showed low intensity (0.270). Thus, EI is a key factor for the SD, as future generations need to have their needs met. This corroborates the research by Severo et al. (2018), as EI contributes significantly to the development of the region in a sustainable way, given that an eco-innovation can be directed towards SD, to preserve natural resources for future generations. According to Orbegozo et al. (2017), EI is an emerging topic among companies, universities, and governments, as they seek efficienty ways of achieving higher levels of SD.

In the hypothesis test for H6, the results indicate that the greatest intensity occurred in the relationship of all the six hypotheses researched (SE=0.789) between the EI→RD, indicating that the greater the use of the EI precepts, the greater the RD perception. These findings aim at the creation of sustainable products, services, and technologies, which are capable of stimulating the local economy with a view to RD (Gouvea et al, 2013; De Guimarães et al., 2018; Amara and Chen, 2020).

All six research hypotheses were confirmed, with four hypotheses (H1, H3, and H6) having close correlations; one hypothesis (H2) with moderate intensity, as well as a hypothesis (H5) with low intensity (Table 4). Among the results, the high intensity of the EI→RD relationship (SE=0.789) stands out, which, based on the perception of citizens, indicates that sustainable innovation can positively influence the development of the region, according to studies by Xavier et al. (2017) and Bossle et al. (2016) sustainable innovation stimulates a new business environment that integrates economic and environmental gains, through new processes and competitive business strategies.

Regarding the contribution to science in the researched area, and concerning the theoretical gap highlighted in the introduction, on the collaboration of HIH with EI in emerging economies (Guerrero and Urbano, 2017), Brazil is an underdeveloped country. This research highlighted that HIH are strong agents for the development of innovations, which contributes to SD and, consequently, RD. In this context, these findings are scientific contributions to companies, governments, and educational institutions that are implementing the HIH, EP, CP, SA, RD, and SD. All these research constructs are also essential for improving people's quality of life, regional development and the preservation of the environment, which can also be linked to SDG indicators.

7 FINAL CONSIDERATIONS

The main contribution of the research is in the evidence that Holistic Innovation Helices (HIH) are predictors of the sustainable innovation process, which is expressed in this research in the Eco-innovation (EI) construct. This finding can contribute to the promotion of public policies to encourage integration among HIH stakeholders, which can include Universities, Government, Transformation Industries, Technological Parks, Spin-off, Incubators, startups, Consulting Teams, Company Shareholders, Suppliers, and Customers.

The integration between the different HIH agents can generate EI that consequently positively influences the promotion of Environmental Practices (EP), Cleaner Production (CP), Social Actions (SA), Sustainable Development (SD), and Regional Development (RD). In this context, this research contributes to the advancement of science by proving that, in the perception of individuals, EI is a strategic drive to significantly increase the elements of environmental sustainability, as well as a potential for Regional Development (RD). Accordingly, the six research hypotheses were statistically confirmed.

Regarding the managerial contributions of the research, we highlight the identification of HIH and EI predictors that significantly influence the constructs of EP, CP, SA, SD and RD. The research findings have a positive impact on managerial decision-making, which aims to better use resources, as EI is the central point for actions aimed at sustainability at the environmental, social, and regional levels. In this sense, organizations should focus on the dissemination of environmental and social actions, to expand the value potential of the company's brand, in addition to philanthropy, reputation, and organizational image (Gold et al., 2018; López-González et al., 2019).

Another important academic contribution of the research is the availability of an analysis framework with the measurement model and the structural model, which was statistically validated (observable variables and constructs). The integrated model (Framework) proposed in the research can be replicated in different regional and international contexts, fostering scientific research and consequently, the advancement of science.

The research presents important findings. However, it has some limitations related to the data collection, as it is based solely on the perceptions of individuals. This perceptions of individuals, using a Likert Scale, can introduce response biases, such as misleading generalization (Halo effect) and Common-Method Variance (CMV) described by Bagozzi and Yi (1991) and Richardson et al. (2009). Therefore, the data were statistically validated using tests of normality, simple reliability, Composite Reliability, tests of variance, and the application of the Confirmatory Factor Analysis Marker proposed by Williams et al. (2003) to identify the possible occurrence of CMV.

Based on the research findings, further studies are suggested to identify other mediating and moderating factors, in order to understand which elements can effectively promote regional development and sustainable development. It is important for science to know the variables that can help governments and other organizations develop policies and actions to promote improvements in people's quality of life, from a long-term triple bottom line perspective. Consistently, both qualitative and quantitative research are suggested, as well as analyzing the perceptions of the different agents involved in these processes.

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