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Cleaner Production practices, motivators and performance in the Brazilian industrial companies

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ABSTRACT

This research develops a relational model between institutional pressures to adopt Cleaner Production and the environmental, economic and operational performance impacts of such practices. Thus, by using a survey with a sample of two hundred and eight (208) Brazilian industrial companies, it was possible to evaluate the principal motivators driving Cleaner Production in these companies, define measures for the levels of adoption of such practices and analyse their contributions to environmental, economic and operational performance. It was concluded that all institutional pressures exert a positive influence on the levels of adoption of such Cleaner Production practices by the companies, with the pressure exerted by the productive chain, of which the companies form a part, particularly standing out, as well as the pressure from internal and external stakeholders. Moreover, it was concluded that the companies' environmental, economic and operational performance is positively impacted by Cleaner Production practices supported by pressure exerted on the organizations. This study fills a gap in theory by advancing the frontier of knowledge in this field and serving as a reference for environmental public policies that support business guidelines regarding the need for investment in clean technology.

1. Introduction

As a way of guaranteeing the sustainability of their businesses, companies adapt their products and skills to the environmental demands in force. This trend has been steadily increasing since the 1970s, becoming more significant since the 1990s and is constantly growing and evolving. This trajectory accompanies the growth of the pressures exerted on the companies (Subramanian and Gunasekaran, 2015; Matos et al., 2017). As a central axis in the economic strategy of the different industrial sectors (Xiao et al., 2018), manufacturing operations are also largely responsible for the environmental impacts of firms (Lee et al., 2014). As such, they become targets of environmental pressures (Govidan and Hasanagic, 2017; Matos et al., 2017) and present themselves as a range of opportunities for companies to innovate their environmental strategies and practices (Yusup et al., 2014).

According to Zhu et al. (2013a,b) and Subramanian and Gunasekaran (2015), Zhang et al. (2018), institutional pressures are the main motivators for companies to seek environmental practices and innovations in their processes and products. These pressures are divided into basically four groups according to their nature: (i) regulatory pressures that comprise governmental laws and resolutions; (ii) the regulatory pressures represented by the requirements of international, national and client standards; (iii) the pressures from suppliers who understand the supply chain forces of the company; and, (iv) the economic pressures that are represented by the companies' internal cost reductions (Zhu et al., 2013).

Cleaner Production (CP) has been evolving since its inception in

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the 1990s (UNEP/UNIDO, 2004) and is highlighted as the main productive strategy for preventing environmental impacts and resource efficient, especially for its potential to increase operational control and generate financial returns for companies (Oliveira et al., 2017).

CP is divided into hierarchical levels of practical options in terms of environmental performance. On a decreasing scale, the options are as follows: in product design; productive processes; reuse; internal recycling; and external recycling. Although companies widely adopt external recycling, this should not be considered a CP practice because it is not preventive (UNEP/UNIDO, 2004). This alternative would have a proactive character if it could avoid causing minimal impacts to biogenic cycles thanks biotechnologies, among other technologies. If this change happens in the future, in environmental terms this last level of CP application could ascend in the hierarchical structure of CP priorities, because it would present superior environmental performance.

In this business trajectory, understanding the impacts or effects on business performance resulting from changes and environmental adaptations in its operations is still characterized as an important phenomenon in scientific analysis (Peng and Liu, 2016). This evidence occurs because the search for optimization between operational and economic performance is a challenge for industrial companies seeking to remain competitive in the market (Haraguchi et al., 2017).

Within this context, CP presents itself as a necessary strategy for the development of developing countries, such as Brazil. Thus, this research has the purpose of investigating the CP practices of Brazilian industrial companies, based on the research question: What are the practices and pressures for CP in Brazilian industrial companies that are trying to implement CP and what are the impact of CP on environmental, operational and economic performance of these companies?

Therefore, the main goal of this paper is to identify CP practices and pressures in Brazilian industrial companies and to investigate the effects of the CP practices adoption in the environmental, operational and economic performance of these companies. The objectives of this research were accomplished through a research survey applied in 208 (two hundred and eight) industrial companies in the transformation industry. The data were analysed using partial least squares structural equation modelling (PLS) provided by the SmartPLS^3 software.

Sarkis (2012) concluded that cultural and social aspects are crucial to the success of Green Supply Chain Management (GSCM). These aspects are essential for any change in business paradigms, due to their environmental impacts, and can be extended to CP practices, justifying this research on Brazilian industrial companies. In spite of this, the realization of this research in other countries with different social and cultural contexts will allow the comparison of results in a weighted way.

This research presents three main contributions. First, this is a pioneer study analysing measures for the levels of CP adoption practices and evaluating these practices in Brazilian industrial companies. Therefore, this is an important complement to other recent studies on this subject conducted in Brazil (Severo et al., 2015) and in other countries, such as China (Zeng et al., 2010) and Malasya (Yusup et al., 2015). The second contribution consists of identifying and analysing the main pressures that lead to the adoption of CP practices by Brazilian industrial companies. In the literature, review presented in section 2 of the present research, no study was found with such goals.

Finally, this was the first work in the literature to analyse the impacts of CP practices on the environmental, operational and economic performance of Brazilian industrial companies, complementing the work of Severo et al. (2015), which analysed entrepreneurial performance as a unique construct. Some studies have already investigated the effects of environmental approaches on business performance. Zhu, Sarkis and Lai (2013) analysed the pressures for GSCM practices and its effects on operational, economic and environmental performance. Vanalle et al. (2017) analysed this approach in the supply chain of the Brazilian automotive sector, whereas Mohanty and Prakash (2014) investigated GSCM practices by Micro, Small and Medium Enterprises (MSMEs) in India. Following a line of reasoning for the GSCM, yet moving towards a lean and innovation views, Zhang et al. (2018), confirmed a synergetic effect between process innovations, green and lean practices, which play a crucial role towards the improvement of GSC performance. However, these studies were focused on the supply chain and not on the internal scope of production operations, as is the focus of CP.

In the general literature, CP studies can be divided into three main streams of research: technical studies of CP practices; CP success case studies; and CP surveys. In the field of surveys there are few studies on the analysis of CP practices, pressures and impacts on business performance. Zeng et al. (2010), analysed CP impacts and other forms of environmental management on the performance of a group of Chinese companies. Yusup et al. (2015) presented the same approach for Malaysian industries. However, these two surveys were applied considering the latent variable level, that is, without stratifying these constructs at the level of manifest variables and with a reduced scale of variables, which does not allow the detailed understanding of the CP practices in their sub levels.

Severo et al. (2015) studied the relations between the concepts of CP, environmental sustainability and business performance. Nevertheless, they designed a CP construct with a reduced number of four variables and did not focus on CP practices at the activity level. In addition, in Severo et al. (2015), the latent variable business performance was not stratified in its sub-levels and did not include the study of the relations between the pressures on the companies. These CP surveys have approaches similar to our research but focused on the macrolevel of CP as an environmental management strategy. Our research investigates the constructs of CP, Performance and Pressures in a stratified and detailed manner in its sub-levels, represented by first and second-order manifest variables.

After this introduction, this paper is structured as follows: section 2 presents a literature review and the hypothesis development, section 3 presents the research method, section 4 presents the results, section 5 outlines some implications of the study and section 6 draws some conclusions.

2. Literature review and hypothesis development

CP is not yet practised systematically (Tate et al., 2010), being generally adopted as a staff strategy, in a timely manner, thereby losing the expected effectiveness and efficiency.

There are two groups of factors that foment the implementation of CP in companies (Vieira and Amaral, 2015). There is the internal scope of the companies, as for example study Dong et al. (2018) the eco-efficiency indices in relation to water and energy consumption in the Chinese monosodium glutamate industry from CP.

Another factor is in the external context of the company, institutional pressures are the main factor causing companies to look for technologies and innovations that minimize their environmental impacts (González-Benito and González-Benito, 2006; Sarkis, 2012; Zhu et al., 2013, Vanalle et al., 2017, Severo, Guimarães and Dorion (2017); Hens et al., 2018; Ghisellini et al., 2018; Severo et al., 2018; Sousa-Zomer et al., 2018).

Some studies have identified and analysed the influences of institutional pressures on some environmentally sustainable practices in the business environment. Zu, Cordeiro and Sarkis (2013), Mohanty and Prakash (2014), Vanalle et al. (2017), Yang (2017), Zeng et al. (2017) analysed the effects of institutional pressures in the supply chain.

Chen et al. (2018) investigated institutional pressures on one hundred Chinese companies and their effects on Eco-innovation or Green innovation. Another study with this focus was developed by Kawai et al. (2018) in other countries and Severo and Guimarães and Dorion (2018) analysed the CP relationship with corporate social responsibility and eco-innovation practices. In a similar sense, Bhupendra and Sangle (2016) analysed the pressures for clean technologies and clean business strategies, but without going deeper into the practice.

Betts et al. (2018) analysed the influences of institutional pressures on the adoption of sustainable technologies by moderating the production capacity of local firms in Asia, Australia, Europe and North America. This analysis considered a global perspective of companies without going deeper into the operational level. Sousa-Zomer et al. (2018) complement that this transition will lead companies to the concept of Circular Economy.

Zhu et al. (2013a,b) analysed how these institutional pressures influenced the process of implementing the ISO 9001 Quality Management System (QMS) and the ISO 14001 Environmental Management System (EMS). Another study similar to this one was conducted by Castka and Balzarova (2018) and involved fifteen certified companies.

The study by Zhu (2016) analyses institutional pressures and their influences on companies to adopt sustainable production. The author relates the concept of sustainable production to the consumption of materials, water, energy and land from the life cycle perspective. Although this is a similar perspective to CP, its practices are different and are not stratified at the activity level (operational level). Above all, this study is applied to Chinese companies, lacking other samples and other countries for completeness and comparison of the study.

Zhu et al. (2013a,b) adopted three types of drivers, also known as pressures in DiMaggio and Powell (1983), called normative, coercive and mimetic. According to Zhu et al. (2013a,b), normative pressures are due to the demands of the companies' external stakeholders, whereas coercive pressures are related to governmental regulations and legislation, and mimetic pressures refer to market trends and practices, serving as a benchmarking strategy for competitive advantage.

To adapt better to the Brazilian context, these pressures underwent minor conceptual adaptations in our study. Regulatory drivers or pressures refer to government regulations and legislation. Normative drivers refer to the demands of companies' internal and external stakeholders. Demands from suppliers are in line with the requirements of the downstream chain of companies and economic pressures are drivers seeking to reduce operational costs with CP practices.

As one can notice, although some studies point to the importance of institutional pressures as an essential external factor in the search for environmental improvements in companies, to the best of our knowledge, no research has been found that clearly presents the relationship between pressures and the adoption of CP practices at the operational level. Aiming to eliminate this gap and analyse the influence of institutional pressures on the adoption of CP practices by Brazilian industrial companies, the following research hypotheses were adopted:

Hypothesis 1. - Institutional pressures positively influence industrial companies to adopt CP practices.

- **H1a** - Institutional pressures positively influence industrial companies to adopt CP practices in the production process;
- **H1b** - Institutional pressures positively influence industrial companies to adopt CP practices in product design;
- **H1c** - Institutional pressures positively influence industrial companies to adopt CP practices in Internal Recycling.

On the other hand, within the organizations, the predominant factor is the economic return on CP projects, which conditions the adoption of these practices by industries (Shi et al., 2008; Dobes, 2013; Scarazzato et al., 2017). The major challenge for Sustainable Operations Management is to evaluate and overcome the trade-offs arising from CP practices in its strategy and under its different paradigms (Carvalho et al., 2014).

Silva et al. (2017) claim that companies can obtain more profit from their businesses by reducing waste and treating/disposing of it, in addition to avoiding fines for non-compliance with environmental legislation.

Thus, the search for the optimization between environmental, operational and economic performance is a key point for the dissemination of CP practices in all industrial environments, since companies would not be willing to undertake CP if it presents negative impacts on their operations and finances (Haraguchi et al., 2017; Ramos et al., 2018).

Some studies have relied on this perspective as the purpose of realization. Zhang et al. (2018) proposed a model to evaluate CP maturity based on its results in reducing rates of pollution generation and resource consumption.

Zhang et al. (2015) analysed the increased efficiency of resource use at different levels as a result of CP implementation in a case study in a Chinese industry. Khuriyati and Kumalasari (2015) concluded that a proactive CP approach generates more significant environmental results than the end-of-pipe approach in the cracker industry. Since Zhang et al. (2018) advance by defining the concept of “cleanliness level index” to make the hierarchical priorities of CP application levels more understandable.

Guimarães et al. (2018) studied the influence of entrepreneurial orientation, market orientation and knowledge management orientation in CP implementation. Finally, Severo et al. (2015) concluded that CP is positively related to the organizational performance of companies in the Brazilian metal-mechanic industry. Thus, to complement the study by Severo et al. (2015), we sought to analyse this relationship with the environmental, operational and economic performance of Brazilian industries in different segments.

There are some studies based on the environmental assessment of processes and products that, through simulations, indicate that CP practices would increase the environmental performance of companies. However, no study that shows the effect of the implementation of CP practices on the environmental, operational and economic performance of companies was found. Thus, the following hypotheses are put forward:

Hypothesis 2. **-** The adoption of CP practices positively impacts industrial companies' performance.

- **H2a.** CP positively affects processes' environmental performance.
- **H2b.** CP positively affects products' environmental performance.
- **H2c.** CP positively affects operational performance.
- **H2d.** CP positively affects economic performance

Fig. 1 depicts the research model that constitutes the basis of our analysis. The measurement model, discussed in the next section, will describe in detail the composition of the constructs.

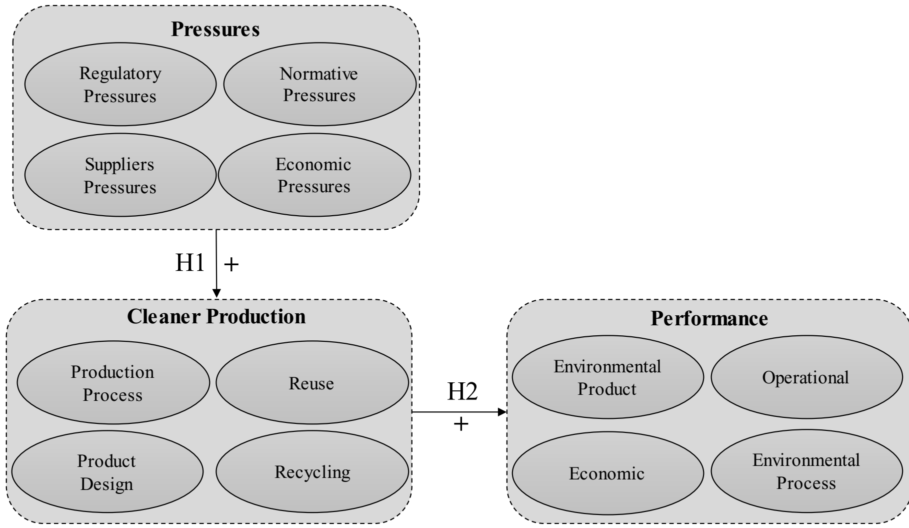

Fig. 1. Conceptual model.

3. Research method

To test the hypotheses proposed by this paper, a survey was conducted as per Forza (2002). The data collection instrument was a questionnaire structured using the Semantic differential-scale, in which 1 represents “Strongly Disagree” and 7 means “Strongly Agree".

There are some papers that perform surveys related to CP, such as Howgrave-Graham and Berkel (2007); Yüksel (2008); Zeng et al. (2010); Severo et al. (2015); Yusup et al. (2015); Severo, Guimarães and Dorion (2017); e Guimarães, Severo and Vieira (2017). However, any of this research presented a systematic procedure to develop a measure for CP. Therefore, we built on a simple multi-item scale construct for CP from United Nations Environment Programme (2004). The CP is comprised of three practices (constructs): Production Process Modifications, Product Design Modifications and Reuse and Recycle Internal.

With regard performance, the environmental performance relates the ability of manufacturing plants to reduce air emissions, effluent waste and solid wastes and the ability to decrease consumption of hazardous and toxic material. The Operational Performance relates to the manufacturing plant's capabilities to more efficiently produce and deliver products to customers. The items related to environmental and operational performance were adapted from the paper of Zhu et al. (2013a,b). The variables concerning the respondent and the company characterization were adapted from SEBRAE (2010) and Synodinos (2003). Table 2 present all the constructs and items of the research. We used pressures from the work of Zhu et al. (2013a,b) and Zhu (2016).

In order to ensure face and content validity we performed interviews with two academic experts. Expert A works with Sustainable Supply Chain and CP. Expert B works with CP, Operations Management and also has a large experience with scale development and multivariate statistical methods. Eight rounds of interviews were accomplished with both experts in order to organize items within the three main constructs of CP (Production Process Modifications, Product Design Modifications, Reuse and Recycle Internal) and also to validate the other items of the questionnaire. Each of the constructs consists of at least 3 items (manifest variables).

As there is no formal register of companies that practice CP in Brazil, we firstly contacted CP managers at random, with the use of the LinkedIn network. The research based on this sample is: observational, cross-sectional and non-probabilistic (Forza, 2002). As our sample is nom-probabilistic we establish the criteria that the company would be contacted to participate in the research only if we could find a manager of this company on LinkedIn network who deliberately claim to work with CP.

According to Podsakoff et al. (2003), such criteria addresses an important source of common method bias, particularly because we could select more than one manager working in the same company. In addition, we also adopted other techniques suggested by Podsakoff et al. (2003) to minimize source of common method bias: we randomly sorted items within each construct and also made it clear to respondent that his/her name and the company information would be kept anonymous. A final population of nine hundred companies resulted from this procedure. In order to present more evidence that these companies were doing efforts to implement CP, we also searched a report from CETESB (São Paulo State Environmental Company) which presents companies that are developing

Table 1

Case	Production Processes			Product Design			Recycling (internal)			Mode	Median	Status
	prodprocess1	…	prodprocess12	proddesign1	…	proddesign3	internalrecy1	…	internalrecy3			
1	6	…	5	4	…	6	5	…	5	5	5	included
2	7	…	6	4	…	4	4	…	5	4	4,5	included
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
207	2	…	3	2	…	1	4	…	3	2	2,5	excluded
235	5	…	4	4	…	5	6	…	5	5	5	included

actions towards sustainable production. All of our nine hundred companies are listed in this report.

The survey was performed using a web survey platform (Qualtrics). In total, nine hundred questionnaires were sent to our population. Two hundred and fifty-six questionnaires were answered. In order to be sure that the companies used CP practices we firstly asked to the interviews to complete a CP assessment questionnaire. This questionnaire presented all the CP practices and the interviews were asked to present in a Semantic differential-scale ranged from 1 to 7 the degree of adoption of each CP practice in his company. Table 1 shows the results from these evaluations. As cut-off criteria for composing the final sample, Mode and Median were adopted with values less than or equal to 3.0 (Mode≤3.0; Median≤3.0).

If for a company any of the CP practice had an implementation level above 3.0, we considered that there was no evidence that this company has been adopting CP. So, fourty eighth cases were excluded of the research sample. Otherwise, the company has been doing efforts towards CP and could participate in our study. Thus, the total research sample consisted of two hundred and eight companies. The characteristics of the companies and their respondents, which formed the research sample, are presented in Table 2.

The sample has a higher percentage of large companies. In general, it is a sample of companies with international relationships, indicating the existence of motivators or internal pressures to adopt CP practices.

Estimation of the research model is made through partial least squares (PLS) analysis. PLS is a second-generation structural equation modelling technique developed by Wold (Haenlein and Kaplan, 2004). PLS path analysis has several advantages in comparison with covariance-based structure analysis. PLS requires a smaller sample size, and normality assumption is not required (Sarsdet, 2008). The Smart-PLS Ringle et al. (2005) was used.

4. Results

The measurement model presents the relationships between each block of indicators (manifest variables) and their latent variable. Before testing the hypotheses from the research model, an assessment of the constructs' psychometric properties (reliability, convergent validity, and discriminant validity) was performed. The results of the measurement model are given in Table 3.

Table 2
Characterizing the research sample.

Role of the respondent in the company	Total	Percentage (%)
Owner	6	2.88
Director	13	6.25
Manager	68	32.69
Supervisor	58	27.88
Technician	63	30.29
Company size		
≤9 employees	2	0.96
10–99 employees	17	8.17
100–499 employees	29	13.94
≥500 employees	160	76.92
Company export Sales Revenue		
No exports (0%)	66	31.73
From 0.1 to 24.9%	88	42.31
From 25.0 to 49.9%	29	13.94
From 50.0 to 74.9%	8	3.85
Above 75.0%	17	8.17
Company main production type		
Make to Stock (MTS)	66	31.73
Make to Order (MTO)	96	46.15
Assemble to Order (ATO)	26	12.50
Engineer to Order (ETO)	20	9.62

As presented in Table 3, the results of the reliability test showed that all the scales were reliable, with outer loadings (>0.7) (Hair et al., 2011), Cronbach's α (>0.7) (Götz et al., 2010), Composite Reliability (CR) (>0.7) (Nunnally and Bernstein, 1994), and Average Variance Extracted (AVE) (>0.5) (Hair et al., 2009). Content validity was established through extensive literature review and iterative construct review by researchers.

The manifested variables with loads lower than these cut criteria were eliminated from the model. This procedure occurred through iterative cycles with the objective of reaching constructs (latent variables) with values of AVE>0.5 and, thus, obtaining the final model.

To evaluate the discriminate validity of the measurement model, the Fornell Larcker criterion was applied to compare the square roots of the AVE value of each construct with correlations between the focal and other constructs. As shown in Table 4, the square root of the AVE value of each construct is greater than the correlation between that construct and the other constructs, suggesting acceptable discriminant validity (Fornell and Larcker, 1981; Anderson and Gerbing, 1988).

The above analysis shows that the criteria of the measurement model are reliable and valid. To better represent the conceptual model described in Fig. 1, a reflexive-reflective upper order structural model was used (Becker et al., 2012). Fig. 2 illustrates the higher order structural model.

The hypotheses $H1_{a\text{-}c}$ and $H2_{a\text{-}d}$ are indirect effects of the central hypotheses and were not re-presented in the model.

The pressures were represented as a second-order latent variable. This was subdivided into four first-order latent variables: Economic pressures; Normative pressures; Regulatory pressures; and Supplier demands. These variables were based on the theoretical study by Zhu et al. (2013a,b). However, as Zhu et al. (2013a,b) deal with pressures related to Green Supply Chain Management (GSCM) practices, the study variables were adapted to the scope of CP for the purposes of this research.

CP practices were initially supported by (United Nations Environment Programme, 2004) and were developed and tested in this present study. They were divided into three first-order latent variables: Product design; Productive processes; and Internal recycling.

Variables related to the company's performance were based on the work of Zhu, sarks and Lai (2013). Again, the variables were adapted to the reality of CP practices. The latent variable Performance was divided into four first-order latent variables: Environmental Performance of Processes; Environmental Performance of Product; Operational Performance; and Economic Performance.

Once the final model was established, the research hypotheses were tested, and these can also be visualized graphically by the final model obtained. Fig. 3 represents the final structural model, with the representative effects of the hypotheses containing latent variables of the first and second orders.

The values of the path coefficients represent the standardized beta coefficients of least squares regressions (X^2). The magnitude and significance of these coefficients, given the directions established between the latent variables, indicate refutation or acceptance of the hypotheses formulated in the research throughout the relational model.

It is important to emphasize that some of the hypotheses of the study are represented graphically by direct paths or direct effects (DE), illustrated in Fig. 2, but the tests performed by indirect paths or indirect effects (IE) should also be considered.

The hypotheses were tested through path analysis (DE and IE) using the Bootstrapping technique (with 5000 subsamples), accepting the hypothesis when $t \geq 1.96$ and rejecting the hypothesis when $t < 1.96$, at a confidence rate of $p < 0.05$ (Hair et al., 2009).

Table 3
Construct measures assessment: reliability and validity.

Latent Variable		Manifest Variable	Code	Loadings	AVE	CR	CA
Pressures	Regulatory Pressures	Federal government environmental regulations	regpress1	0.916	0.769	0.930	0.948
		Regional environmental regulations	regpress2	0.905			
		International countries for export regulations	regpress3	0.846			
		Products potentially conflicting with laws requirements (such as Circular Economy, Producer Responsibility, Occupational Health and Safety, etc.)	regpress4	0.837			
	Normative Pressures	International business requirements for export	normpress1	0.702	0.563	0.900	0.870
		Internal market environmental requirements	normpress2	0.835			
		Brazilian clients environmental awareness	normpress3	0.815			
		Company environmentally responsible image towards to market	normpress4	0.746			
		Media pressure	normpress5	0.724			
		Awareness of society (communities, groups, institutions such as NGOs, etc.)	normpress6	0.718			
		Parent company internal policy (in multinational cases)	normpress7	0.701			
	Demand from suppliers	Supplier advances in product development	demandsupp1	0.928	0.837	0.954	0.935
		Development of an environmental partnership with suppliers	demandsupp2	0.919			
		Track supplier progress in the development of environmentally sustainable packaging	demandsupp3	0.931			
		Suppliers requirements to stay in business (business continuity)	demandsupp4	0.881			
	Economic Pressures	Reduction of costs for disposal of toxic materials/substances and pollutants	econpress1	0.825	0.649	0.881	0.820
		Reduction of the consumption cost (raw material, energy, water, etc.)	econpress2	0.760			
		Getting tax incentive	econpress3	0.779			
		Obtaining financial resources	econpress4	0.855			
Cleaner Production	Production Processes	Cleaning and organizing the production environments/factory floor	prodprocess1	0.816	0.592	0.946	0.937
		Systematic inventory management (raw material/inputs/final products)	prodprocess2	0.745			
		Equipment periodically maintenance	prodprocess3	0.768			
		Improvement and standardization of production process equipment	prodprocess4	0.804			
		Work instructions standardization in productive processes	prodprocess5	0.776			
		Separation of tailings and waste from production processes	prodprocess6	0.765			
		Mechanisms for collecting all tailings types (including spatters and burrs)	prodprocess7	0.707			
		Employees training to carry out cleaner production processes	prodprocess8	0.750			
		Replacement of toxic and/or polluting materials in production processes	prodprocess9	0.705			
		Productive processes control	prodprocess10	0.817			
		Changes in production processes	prodprocess11	0.784			
		Technological changes in production processes	prodprocess12	0.784			
	Product Design	Replacement of toxic and/or polluting materials in product design	proddesign1	0.762	0.711	0.880	0.795
		Changes in product design to improve environmental/ environmental	proddesign2	0.890			
		Employees training to develop cleaner products	proddesign3	0.871			
	Recycling (Internal)	Wastes reuse from one production process as by-products for other company production processes	internalrecy1	0.816	0.734	0.892	0.819
		Water reuse used in a productive process as a resource for other company processes	internalrecy2	0.856			
		Energy utilization of a productive process as a resource for other company productive processes	internalrecy3	0.897			
Performance	Product's Environmental Performance	Increasing the recycling capacity (recyclability) of products	envperfproduct2	0.243	0.473	0.694	0.393
		Increased energy consumption of products	envperfproduct3	0.793			
		Decreased use of toxic and/or polluting materials in products	envperfproduct4	0.856			
	Processes Environmental Performance	Decrease in atmospheric emissions from production processes	envperfproc1	0.759	0.635	0.924	0.903
		Decrease in industrial wastewater generation from pro-active processes	envperfproc2	0.795			
		Decrease in the generation of solid waste from production processes	envperfproc3	0.850			
		Decreased consumption of materials and/or toxic and/or polluting substances in production processes	envperfproc4	0.795			
		Decreased consumption of electricity in production processes	envperfproc5	0.831			
		Decrease in water consumption in production processes	envperfproc6	0.824			
		Consumption reduction of the raw material in productive processes	envperfproc7	0.715			
	Operational Performance	Decrease in stock levels of the company	operperf2	0.755	0.518	0.757	0.540
		Increased customer satisfaction	operperf3	0.527			
		Decrease of tailings rates in our production processes	operperf4	0.839			
	Economic Performance	Decrease in the purchasing cost of materials	economicperf1	0.801	0.669	0.858	0.753
		Decrease in the energy consumption cost	economicperf2	0.813			
		Decrease in operating costs	investperf2	0.840			

Legend: CR, composite reliability; AVE, average variance extracted; CA, Cronbach's Alpha (α).

Table 4
Discriminant validity: Fornell-Larcker criterion.

	Constructs	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Pressures	Regulatory(1)	**0.878**										
	Normative(2)	0.761	**0.750**									
	Suppliers(3)	0.624	0.777[a]	**0.915**								
	Economic(4)	0.573	0.678	0.657	**0.805**							
CleanerProduction	Production Process(5)	0.227	0.468	0.384	0.348	**0.769**						
	Product Design(6)	0.223	0.444	0.439	0.312	0.669	**0.843**					
	Internal Recycling(7)	0.318	0.464	0.399	0.414	0.346	0.325	**0.857**				
Performance	Product's Environmental(8)	0.093	0.105	0.084	0.130	0.223	0.227	0.146	**0.688**			
	Processes Environmental(9)	−0.063	0.016	0.024	0.033	0.265	0.220	0.140	0.690[a]	**0.797**		
	Operational(10)	−0.002	0.075	0.001	0.010	0.294	0.285	0.037	0.331	0.519	**0.719**	
	Economic(11)	−0.008	−0.027	−0.010	0.054	0.062	0.019	0.034	0.334	0.542	0.465	**0.818**

[a] Note: Two occurrences did not meet the Fornell-Larcker criterion. However, the difference was of an insignificant order of magnitude and, therefore, it was accepted as validly fulfilling the criterion.

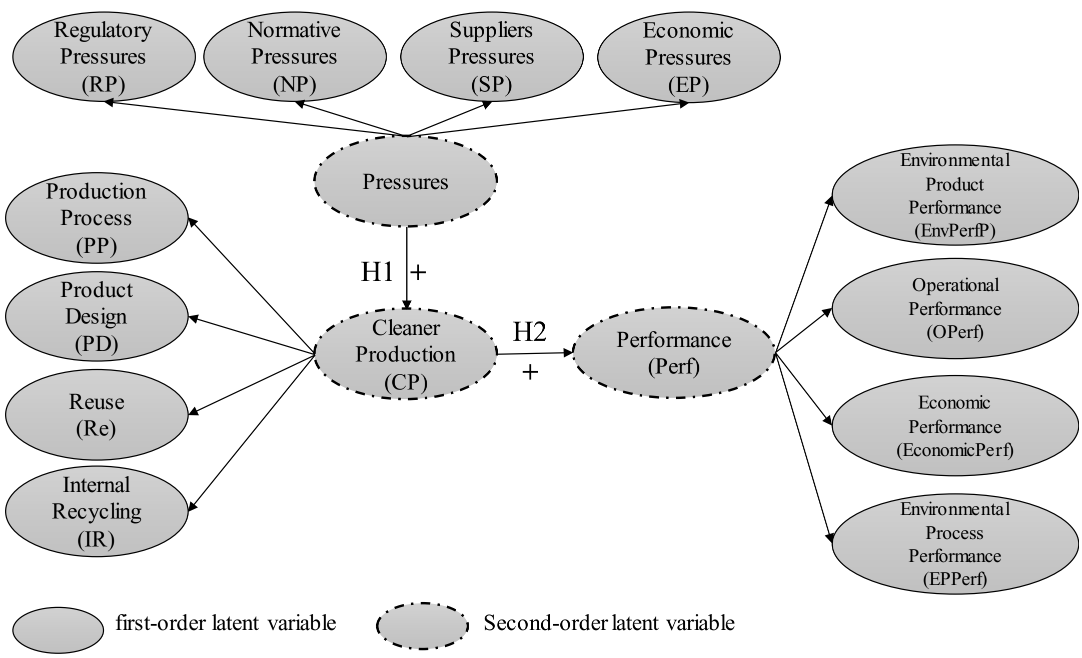

Fig. 2. Hierarchical structural model.

The results of this test are shown in Table 5.

The hypotheses were tested using DE and IE. These tests presented values of $t \geq 1.96$ and were accepted. It can be noted that, in the case of Hypothesis 1, there is statistical evidence of the direct effect of pressures on the adoption of CP practices. Although there is no certification and legislation for CP, pressures or motivators drive companies' adoption of CP practices. It should be recalled that, from the analyses of the final model (Fig. 2), there is a decreasing order of impact from the pressures exerted on companies to adopt CP. In descending order, the pressures are: Normative pressures; Supplier demand; Regulatory pressures; and Economic pressures. By analysing the indirect effects (H1a-c), the most influential practice was the production process.

Regarding Hypothesis 2, there is statistical evidence of the CP practices' direct effect on company performance. The indirect effects (H2a-d) show that CP practices had a greater effect on Processes environmental performance and Product environmental performance.

5. Discussion

The discussion begins with the theme of the pressures for Brazilian industrial companies to implement CP practices. CP practices are mainly used to improve productive processes, which are, in a way, relatively easier to implement, with the exception of technological changes involving paralysis, higher costs and higher investment values. It is important to highlight the importance of market pressures on improvements in production processes.

The main norm that motivates the adoption of CP practices is the ISO 14001: 2004, in which Oliveira et al. (2017) showed requirements met by CP practices. Consideration should be given to moving to the 2015 version of the standard, which has made it more stringent. In this sense, it is expected that this normative pressure will be more intense for the adoption of CP practices. However, it is not yet possible to measure this relationship, as companies are still in the transition period in search of ISO 14001: 2015 certification.

Product improvements are strongly influenced by pressures

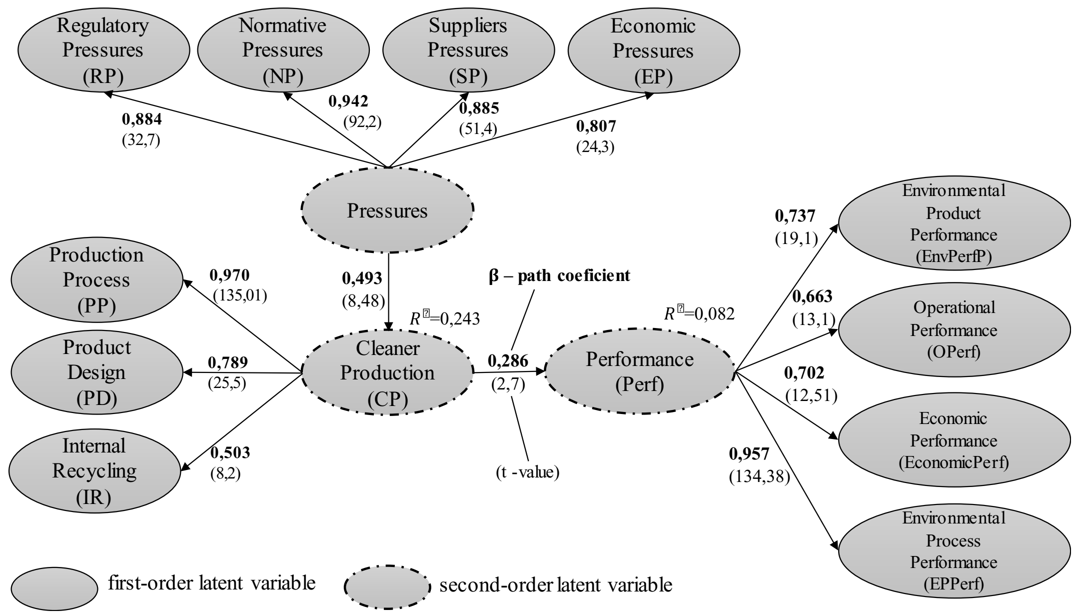

Fig. 3. Final hierarchical structural model.

Table 5
Analyses of the direct and indirect paths in the hypotheses.

Hypotheses	Brief description of hypotheses relationships	Original Sample	Sample Mean	Standard Deviation	*t* Statistics	*Result*
H1	**Pressures → Cleaner Production (CP)**	**0.493**	**0.49**	**0.057**	**8.679**	**Accept**
H1a	Pressures → Production Process	0.478	0.475	0.055	8.647	Accept
H1b	Pressures → Product Design	0.389	0.387	0.049	7.875	Accept
H1c	Pressures → Internal Recycling	0.248	0.249	0.047	5.308	Accept
H2	**Cleaner Production (CP) → Performance**	**0.286**	**0.296**	**0.057**	**8.679**	**Accept**
H2a	CP → Environmental Performance of Processes	0.273	0.283	0.101	2.702	Accept
H2b	CP → Environmental Performance of Product	0.211	0.218	0.078	2.689	Accept
H2c	CP → Operational Performance	0.189	0.197	0.071	2.665	Accept
H2d	CP → Economic Performance	0.200	0.205	0.072	2.794	Accept

exerted by suppliers. In this type of practice, the importance of regulatory pressures and supplier demand is even more noticeable. This same evidence was found for GSCM, according to the study by Zhu et al. (2013a,b). Normative pressures promote competitiveness among companies in the market, which is directly influenced by pressures exerted by suppliers, as the drivers are located both upstream and downstream of the companies, which ends up closing the productive chain to which they belong, which is in fact extremely important for the sustainability of their products, and therefore of the businesses themselves, in the market. This information complements the study by Severo et al. (2015) in the Brazilian automotive metal-mechanic cluster, and Matos et al. (2017), which emphasize that customers influence companies' CP practice since last ten years of these strategy.

It is possible to observe from the results presented in Fig. 3 that legal requirements are not as significant motivators as the market pressure itself, exercised through non-compulsory norms and the supply chain in which the companies are inserted. Guimarães, Severo and Vasconcelos (2018) already predicted the search for the competitive advantage focused on the rise of the corporate image through the CP use.

The last version of the National Policy Law for the Environment (PNMA), which deals with the preservation, improvement and recovery of environmental quality, was published in August 1981 (Brasil, 1981). This law emphasizes that all activities that affect the environment or potentially polluting cannot function without proper licensing, which includes establishing a plan for the prevention, monitoring and management of environmental impacts. The industrial sector is considered as one of the main sectors targeted by this law. In this regard, according to Sousa-Zomer et al. (2018), CP plays a key role in the micro-level transition to a circular macroeconomy.

In this sense, it is observed that Brazilian legislation may be out of date and needs to be revised and more rigorously reformulated. Thus, it is expected that regulatory pressures will play a more intense role in adopting more advanced CP practices. On the other hand, Severo et al. (2015) concluded that, specifically in the Brazilian automotive sector, this type of pressure is more evident. It can be seen that there is an indication that market pressures play a more effective role in the CP practices use by companies, since the automotive sector has been distinguished by the dissemination of environmental practices along its production chain, as pointed out Vanalle et al. (2017).

Economic pressure exerts less influence on CP implantation by companies, although a statistically significant value for this motivator has still been observed. It should be noted that companies still adopt CP practices in the form of isolated projects and, at the planning stage, there is a careful calculation for the economic payback of each of these projects.

There is a strong paradox. On the one hand, Brazilian companies implement only CP projects with high potential for financial returns (Oliveira et al., 2016) or, in according Zeng et al. (2010), the Chinese industries implemented CP projects with low costs. On the other hand, there is no significant economic pressure from environmental agencies and the Brazilian government to allow the adoption of more practices that prevent and reduce industrial environmental impacts.

In this relation, there is a link between the legal pressures, upstream of the companies, and the economic performance expected by the CP practices by the companies, downstream of their industrial activities. In other words, it can be noted that normative parameters related to industrial environmental impacts could be more rigorous, in order to stimulate companies to seek environmental innovations in their production processes, and also that government pressures may be more fiscal and financial.

Thus, companies are passively positioned in the face of their opportunities for environmental improvements, while the paradox presented supports a vicious cycle that does not demand new investments to improve environmental performance.

Internal recycling practices present themselves as a potential trade-off in relation to quality and customer requirements, as they generate uncertainties about their impacts on these requirements. The major driver for this type of CP practice is reducing costs and maximizing profits through reusing inputs within the productive processes. However, the relatively low adoption of this type of practice can be explained by the relatively low influence of economic pressures on companies. Severo, Guimarães and Dorion (2018) observed that CP practices can improve the quality of products from the perspective of consumers, and Zhu et al. (2013a,b) and Matos et al. (2017) founded that CP practices tend to improve the quality of products under the producer's point of view.

The discussion continues by analysing the influences of CP practices on the productive performance of Brazilian industrial companies. The difference between this and the other three latent variables of performance is relatively small. What is presented here reinforces the discussion on the positive impacts of CP practices on companies' environmental, economic and operational performance as pointed out Guimarães et al. (2018) and Severo et al. (2018). This same relationship was identified in the GSCM practices of the Brazilian automotive sector (Vanalle et al., 2017) and Chinese manufacturers (Zhu et al., 2013; Zhu, 2016).

It can be concluded, therefore, that companies' environmental, economic and operational performance is positively impacted by CP practices, and these are supported by the pressures exerted on the organizations. However, the relatively low values can be attributed to two different factors: limitations in measuring these variables due to companies' fear of answering these questions accurately; and low adoption of internal recycling and reuse of inputs in productive processes that bring more significant and rapid economic returns.

Economic performance reflected the most positive impact of the adoption of CP practices, as was to be expected from the research developed by Oliveira et al. (2016). As discussed earlier in the analysis of Hypothesis 1, Brazilian industrial companies seek to implement CP projects with high potential for financial returns. That is, companies neglect the high environmental potential of this strategy in favour of the need for economic payback, which compromises CP's real objective.

Notably, the productive processes' environmental performance is strongly impacted in a positive way by CP practices, which was already expected from a productive environmental strategy and which has already been foreseen by Ghisellini et al. (2018) and Dong et al. (2018).

Another important confirmation of this research is the strong and positive influence of CP implementation on the products' environmental performance. In this way, it can be concluded that CP has great potential for the Life Cycle Management (LCM) and Life Cycle Engineering (LCE) of the products, expanding their scope of performance outside the scope of manufacture, pointing also to Sousa-Zomer et al. (2018).

Finally, the hypotheses raise an important conclusion that CP practices also positively impact the operational performance of industrial companies. This information serves to breakdown obstacles such as prejudices, resistance to change, and others that undermine adherence to this productive environmental strategy.

6. Conclusion

Through the proposal of this research, it was possible to develop a relational model between institutional pressures, CP practices and environmental, economic and operational performance, enabling greater understanding of these theoretical constructs composed of observable variables in business practice.

After this introduction to the conclusion of this research, this section has been divided into three subsections to highlight the scientific contributions, practical contributions and limitations of the research and recommendations.

This paper fills a gap in the theory, thereby advancing the frontier of this field of knowledge. The research analysed measures the levels of adoption of CP practices and evaluates these practices in Brazilian industrial companies. In addition, the main pressures that lead to the adoption of CP practices by Brazilian industrial companies, and their influences on the environmental, operational and economic performance of Brazilian industrial companies, were identified and analysed.

Companies' environmental, economic and operational performance is positively impacted by CP practices, which are supported by the pressures exerted on the organizations. This relationship between the external pressures, which are downstream of CP industrial options, and the environmental, operational and economic performance resulting from these practices, have not yet been identified in the literature and have been identified and classified by this research. This relational structure can contribute to future studies in order to evaluate which industrial and external variables are essential for the optimization of external pressures and the impacts on business performance.

In addition, it was possible to define and evaluate which key motivators drove CP practices in companies, and what these practices contribute to environmental, economic and operational performance.

Institutional pressures or motivators are extremely important for the acceptance and adoption of CP practices by companies. It is important to highlight the importance of market pressures on improvements to production processes and product designs. Although all pressures have positive influences on companies' adoption of CP practices, it can be seen that the pressures exerted by the productive chain, of which the companies and their internal and external stakeholders are parts, are more important for industrial organizations than regulatory or economic pressures.

These results can contribute in practice as a reference model for environmental public policies that support business guidelines in light of the need for investments in clean technologies.

These results can contribute to the practice of the CP management in companies, since they suggest a link between the external factors (institutional pressures) and internal factors (productive performance) of companies. Thus, managers can adapt the model to the standards and specific characteristics of their company to analyse the best scenario to be adopted.

In this study a survey was carried out on a non-probabilistic sampling for convenience in a data base of companies which are doing efforts towards CP. However, these companies do not represent the entire list of companies implementing CP in Brazil. To the best of our knowledge, such database does not exist. Thus, there is a limitation of statistical inference, which compromises the generalization of this research results. Thus, a significant expansion in the size of the sample is necessary so that the results can be generalized to the population of Brazilian industries that are implementing CP.

Another limitation of the research involves companies' economic performance. This limitation may be due to two different factors: companies' fear of responding accurately to questions on economic issues; and low adoption of internal recycling and reuse practices of inputs in productive processes that bring more significant and rapid economic returns.

Although this study was carried out in Brazilian industrial companies, there is no evidence suggesting that generalizing the results to other countries and different economies is not possible, meaning that the results can be used by the international academic and business world. However, this statement does not mean that this research is not needed in other countries or economies. In contrast, the statement is a suggestion for future research.

In future studies, it is recommended to apply empirical research methods, such as simulations and operational research, that allow a measurement of the influence of CP practices on the environmental, operational and economic performance of companies. As for the pressures, it would be necessary to apply surveys, having as subjects the pressing actors, such as governments, suppliers, consumers, society in general, and all stakeholders involved in the chain.

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