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Article

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Input-output-outcome innovation model: an analysis of the Brazilian manufacturing companies

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Abstract

Purpose – The objectives of this study are to identify which inputs are most relevant for development and successful introduction of product and process innovations and identify the impacts of these two types of innovation on the performance of Brazilian manufacturing companies.

Design/methodology/approach – This study analyzes the relationships between input, output and outcome for a sample of 5,586 Brazilian manufacturing companies by using partial least squares structural equation modeling (PLS-SEM).

Findings – The results indicate that (1) product innovations are favored by internal resources, (2) process innovations are favored by external resources, (3) product innovations mainly affect a range of products offered by companies and (4) process innovations mainly affect performance in manufacturing capacity, flexibility and costs.

Practical implications – By identifying the main efforts to improve the innovation performance and input-output-outcome relationships, the results can contribute to a better decision-making process for innovation investments and management in companies as well as for policymakers. The results are particularly relevant given that the Brazilian case can serve as a reference for other emerging countries.

Originality/value – Analyses of the innovation in input-output-outcome relationships were performed in a comprehensive way by using a set of variables for defining each construct. This allowed each construct to be better measured, which improved the understanding of the relationships between inputs and outcomes mediated by product and process innovations.

Keywords Innovation inputs, Innovation outputs, Innovation outcomes, PLS-SEM, Manufacturing sector, Innovation policy, Innovation management

Paper type Research paper

Introduction

Innovation activities play an important catalyst role in improving the growth, performance and competitiveness of companies. However, there is the assumption that companies in emerging markets have greater difficulties, such as in technological capabilities, which can lead to different results in the innovation process (Charmjuree, Badir, & Safdar, 2021). Given the complexity of the institutional environment, it is risky to generalize consolidated theories of established markets

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Erratum: It has come to the attention of the publisher that the article, Lizarelli, F.L., Ishizaka, A.Y. and Toledo, J.C.d. (2024), "Input-output-outcome innovation model: an analysis of the Brazilian manufacturing companies", *Innovation & Management Review*, Vol. ahead-of-print No. ahead-of-print. <https://doi.org/10.1108/INMR-01-2023-0008>, was published without including the article's associate editor, Rafael Morais Pereira. This error was introduced in the production process and has now been corrected in the online version. The publisher sincerely apologises for this error and for any inconvenience caused.



to emerging economies (Wang, Xiao, & Savin, 2020). Thus, doubts remain regarding the relationship between innovation and company performance in emerging countries (Gupta, 2021).

A few studies have distinguished the concepts of innovation inputs, outputs and outcomes (IOO), which can lead to misunderstandings about innovation as a driver of the firms' performance (Janger, Schubert, Andries, Rammer, & Hoskens, 2016; Tavassoli, 2018). Companies can transform innovation inputs (internal or external) into intermediate outputs in the first stage and then potentially into innovation outcomes in the second stage (Janger *et al.*, 2016). Output refers to the direct results of innovative efforts (i.e. product, operational and process innovation), whereas innovation outcomes are the consequences of the introduction of innovations (i.e. market and product performance) (Janger *et al.*, 2016; Tavassoli, 2018). The distinction between product and process outputs in terms of innovation is also relevant as they can be impacted by external and internal inputs in different ways and can also impact the outcomes (Medda, 2020; Wang *et al.*, 2020).

There is an association between innovation inputs – to be translated into investments in research and development (R&D) and patents and economic advancement – although this relationship is widely studied and confirmed in developed economies (Gupta, 2021). There is also an assumption that companies in emerging markets have insufficient R&D and technological capability (Charmjuree, Badir, & Safdar, 2021). In this sense, there is a gap in the literature on whether R&D is related to product and process innovation in industrial companies with low R&D investment (Carvache-Franco, Gutierrez, Guim-Bustos, & Carvache-Franco, 2020). Additionally, doubts remain about the relationship between innovation outputs and company performance in emerging countries (Gupta, 2021). This makes empirical studies of innovation in company performance in emerging countries through observation of multiple dimensions (e.g. market, product and operational) relevant (Carvache-Franco, Gutierrez, Guim-Bustos, & Carvache-Franco, 2020; Gupta, 2021; Charmjuree *et al.*, 2021).

A better understanding of the input-output-outcome relationships in the context of emerging countries could guide the design and implementation of public policies for high-quality growth (Zhou *et al.*, 2021), even more in countries like Brazil where continued public policies are required to encourage and support innovation (Santos, Basso, & Kimura, 2018; Colombo & Cruz, 2023). Emerging markets are distinguished from developed markets through characteristics such as smaller *per capita* income and more price-conscious and price-sensitive consumers. As many consumers in emerging markets come from low-to-middle class, with modest income and limited access to goods and services, innovation has a positive impact on the perceived value by increasing perceived gains in relation to acquisition costs (Shankar & Narang, 2019). In this context, this study aims to answer questions which still require further clarification, especially regarding the emerging countries scenario:

- RQ1. What is the effect of internal and external inputs on product and process innovation?
- RQ2. What is the effect of product and process innovation on innovation outcomes (i.e. product, operational performance and market)?
- RQ3. What is the indirect effect of internal and external inputs on innovation outcomes (i.e. product, operational performance and market) mediated by product and process innovation?

Thus, this study seeks to address the following research gaps: (1) identifying the impact of R&D and other internal and external inputs on product and process innovation (outputs); (2) analyzing the relationship between these different types of innovation in dimensions of company performance (outcomes); (3) proposing a model for analysis of these relationships in an integrated way; (4) using a set of variables to compose each construct for allowing better measurement of each construct and (5) improving understanding of the relationships between inputs and outcomes mediated by product and process innovation. For this purpose,

a sample of 5,586 manufacturing companies was obtained from a database provided by the Brazilian Institute of Geography and Statistics (IBGE).

Theoretical review

A model of relationships between IOO was proposed for analysis of the relationships between different types of innovation in multiple performances constituting a dynamic capacity, in which input is divided into internal (or in-house) and external (Medda, 2020; Orsi, Neuberger, & Cário, 2019). Differentiation in the analysis of the impact of input on the innovation process is one of the examples in the existing literature (e.g. Bianchini, Pellegrino, & Tamagni, 2018). Internal inputs are related to investment in the creation of new knowledge and solutions, whereas external inputs are related to extramural R&D, acquisition of machinery and external knowledge, which can increase the innovative capabilities (Bianchini *et al.*, 2018; Guarascio & Tamagni, 2019; Medda, 2020).

The distinction between product and process innovation outputs is also relevant, as these innovations can be impacted in different ways by external and internal inputs, in addition to impacting the outcomes (Haneda & Ito, 2018; Medda, 2020; Wang *et al.*, 2020; Vargas, Lloria, Salazar, & Vergara, 2022). In the case of a product, it was observed whether the innovation is aimed at the company, domestic market or world (Song & Chen, 2014). As for the process innovation, type of innovation (i.e. production method, logistics or software) (Karabulut, 2015) and degree of innovation (i.e. new to a company or new to the industry) (Reichstein & Salter, 2006) are considered.

Additionally, the influence of input mechanisms can differ when considering product and process innovations. There is a tendency in emerging countries for product innovation outputs to be positively impacted by internal R&D investments and/or inputs, although internal inputs can positively impact the process innovation outputs in the context of developing countries (Paily, 2018).

In Brazilian industries, some studies have shown evidence that internal R&D efforts positively influence product and process innovations (Dall Corte, Dabdab, & Stiegert, 2015). On the other hand, Goedhuys and Veugelers (2012) observed that Brazilian companies are less successful in fostering an internal development strategy. The focus of Brazilian companies on internal knowledge through in-house R&D tends to generate innovations linked to emerging technologies (Franco, Ray, & Ray, 2011). Considering the above arguments, we can propose the first hypotheses as follows:

- H1a.* The relationship between the use of internal inputs and product innovation output is positive.
- H1b.* The relationship between the use of internal inputs and process innovation output is positive.

Understanding the impacts of external inputs on innovation development is important because although studies have shown that emerging economies can catch up with developed countries by imitating or adopting technologies, this scenario can quickly change with the increase of global competition (Zhou *et al.*, 2021). Companies in emerging markets suffer from a lack of knowledge and capabilities (Zanello, Fu, Mohnen, & Ventresca, 2016; Wang *et al.*, 2020), and for this reason, strengthening connections with external technological knowledge sources can yield results which cannot be internally achievable in the short term (Charmjuree *et al.*, 2021). The technological dynamics make it almost impossible for companies to develop and update the necessary knowledge and explore external sources of knowledge (Wang *et al.*, 2020).

Process innovation in Latin American developing countries is largely driven by buying strategies (e.g. external R&D and licensing of patents) (Crespi & Zuniga, 2012), whereas product innovations are highly dependent on the acquisition of external knowledge and

technology (Gonçalves, Lemos, & de Negri, 2008). Additionally, in emerging countries, technology acquisition is found not to be effective or significant in process innovations (Paily, 2018). However, the strategy based on industrial machinery and equipment acquisition in Brazilian companies showed a negative effect on innovation outcomes (Frank, Cortimiglia, Ribeiro, & Oliveira, 2016). Acquisition investment tends to gradually improve production processes, but it does not generate innovative capabilities to create strategic advantage in a global scenario (Frank *et al.*, 2016).

External acquisition of equipment is the main investment of the Brazilian manufacturing companies (Orsi *et al.*, 2019), accounting for the largest investments of all innovation activities (Frank *et al.*, 2016). This scenario can affect the innovation performance, especially product innovations (Orsi *et al.*, 2019), due to the relatively low allocation of investment. From these arguments, the following hypotheses are proposed:

H1c. The relationship between the use of external inputs and product innovation output is positive.

H1d. The relationship between the use of external inputs and process innovation output is positive.

The second group of hypotheses (H2) refers to the relationship between outputs and outcomes of the innovation process, in which the former shows whether the company has developed or introduced product and process innovations and the latter shows the impact on performance. This study divides performance (outcomes) into three major constructs: product performance, market performance and operational performance (Lizarelli & Toledo, 2015; Janger *et al.*, 2016; Guimarães, Severo, Campos, El-Aouar, & de Azevedo, 2020).

Innovation outcomes can be seen as the consequences of introducing innovations to the market, process and product performance (Kahn, 2018; Janger *et al.*, 2016; Tavassoli, 2018), thus showing an effect of innovation on the company's performance (Sinha, Saunders, & Raby, 2022). Outcomes can be measured in terms of both product-oriented and operational-oriented results (Lumiste & Kilvits, 2004). Product performance measures the product-oriented effects of innovation, which include improvements in the quality of goods and services and expansion of their variety (Murovec & Prodan, 2009; Hashi & Stojcic, 2013). Operational performance is related to production-oriented innovative performance in which capacity, flexibility, cost reduction and labor cost of the production are considered (Mondéjar-Jiménez, Segarra-Oña, Peiró-Signes, Payá-Martínez, & Sáez-Martínez, 2015). Another factor widely used to highlight the impacts of innovation is the market-oriented results, measured by continued participation in the market and market share (Dervitsiotis, 2010). The innovation outcome can be defined as the orientation toward market penetration and greater market share obtained by the company as a result of innovative processes (Vargas *et al.*, 2022).

The company can gain access to these customers if its product innovation meets the unique needs of consumers in these markets and incorporates more value, resulting in market and revenue expansion, which has a positive impact on the product outcome (Shankar & Narang, 2019; Carvache-Franco, Gutierrez, Guim-Bustos, & Carvache-Franco, 2020). Nevertheless, internal issues can also hamper the positive impacts on performance. A lack of resources and periods of poor management to adequately generate desired outcomes can limit the exploitation of developed innovation (Wang *et al.*, 2020), thus limiting the operational, product and market potential. Product and process innovations have a different impact on the company's performance (Medda, 2020). Although in Brazil, the perception is that there are benefits associated with innovative efforts regarding the quality improvement of products (Frank *et al.*, 2016; Orsi *et al.*, 2019), there are doubts about the impacts of product and process innovations on this outcome. Therefore, the following hypotheses are proposed:

- H2a.* The relationship between product innovation output and product outcomes is positive.
- H2b.* The relationship between process innovation output and product outcomes is positive.

Many studies have associated innovation patterns with sales growth and market success (Guarascio & Tamagni, 2019). The literature dealing with product and process innovations has associated product innovation with market development (Cabagnols & Bas, 2002; Al-Jobor, Al-Weshah, Al-Nsour, Abuhasshesh, & Masa'deh, 2020) as a successful new product that can increase the aggregate value and market share (Janger *et al.*, 2016). Positive results have also been found between process output and market outcome in emerging market countries, such as Vietnam (Canh, Liem, Thu, & Khuong, 2019), India (Paily, 2018) and Brazil (Kannebley, Sekkel, & Araújo, 2020). Bianchini *et al.* (2018) pointed out that different innovation strategies, such as product and process, can have different impacts on market performance and company growth. In this context, we propose the following hypotheses:

- H2c.* The relationship between product innovation output and market outcomes is positive.
- H2d.* The relationship between process innovation output and market outcomes is positive.

Although the process innovation is more related to operational performance, there are a few studies focusing on this relationship (Cabagnols & Bas, 2002; Parisi, Schiantarelli, & Sembenelli, 2006; Hervas-Oliver, Sempere-Ripoll, & Boronat-Moll, 2014). Process innovations can reduce operating costs and generate a competitive advantage in the supply chain (Kalyar, Shoukat, & Shafique, 2019). Because process innovation is mainly production-oriented, performance consequences can be measured by using production process indicators of cost, flexibility and capacity improvement (Janger *et al.*, 2016; Hervas-Oliver *et al.*, 2014). Parisi *et al.* (2006) found that the introduction of process innovation has a sizeable effect on productivity, even being greater than that of product innovation.

Paily (2018) identified in the Indian manufacturing sector that combined product and process innovations influence the productivity growth of the companies. In a study of Brazilian companies, product innovations increased the productivity immediately, whereas process innovations negatively affected it in the first year (Tironi & Cruz, 2008). Therefore, we propose the following hypotheses:

- H2e.* The relationship between product innovation output and operational performance outcomes is positive.
- H2f.* The relationship between process innovation output and operational performance outcomes is positive.

[Supplementary material figure_1](#) show the theoretical framework adopted in this study and research hypotheses. Hypothesis **H1** is associated with research question 1 (**RQ1**), whereas hypothesis **H2** is associated with research question 2 (**RQ2**). Analysis of the relationships between hypotheses **H1** and **H2**, through specific variables of the constructs, is associated with answers to research question 3 (**RQ3**).

Research method

Data and model analysis

The empirical investigation was based on the PINTEC 2014 database (BRASIL. Instituto Brasileiro de Geografia e Estatística, 2016). Data were collected between 2015 and 2016, all relative to the 2012–2014 period and made available for consultation by IBGE from 2018

onward. Data from 5,586 companies belonging to 24 sectors of the industry who had responded to the questionnaire and had some type of innovation in the period were selected for study as follows: 1,095 large companies (>500 employees), 2,371 medium companies (100–499 employees) and 2,120 micro and small companies (<99 employees) (Brazil, 2016).

Partial least squares structural equation modeling (PLS-SEM) is appropriate in situations where a series of regressions are being performed simultaneously, and the regression's dependent variable also represents the independent variable of another regression, thus being chosen for the following main reasons (Hair, Hult, Ringle, & Sarstedt, 2017; Hair, Matthews, Matthews, & Sarstedt, 2017): (1) it is a non-parametric method working well with non-normal distributions and with very few restrictions on the use of ordinal and binary scales; (2) it is used to indicate complex models with a large number of variables *per* construct involving advanced analyses; (3) it is suitable for studies with secondary data and (4) its formative construct allows researchers to perform analysis based on their objectives.

Model and variables

[Supplementary material table 1](#) shows the variables and constructs used to select the variables used to compose the input-output-outcome constructs. The variables were selected according to the PINTEC questionnaire based on the identification of variables presented in the literature which could make up the constructs.

The PINTEC questionnaire evaluates innovation inputs and outcomes on a scale of 1 to 4 based on their importance or impact according to the respondents' perception of expenditures and contributions to different aspects of performance. The variables measure their perceptions over a period of three years, in which outputs are evaluated through binary variables (i.e. whether innovation has been developed by the company or not). The variable PDI_WORLD deals with the percentage of net sales and exports from the introduction of a new product to the world market, being transformed into a binary scale. If there was a value of sales or exports, then the company was innovated within the world market (1 = Yes); otherwise, there was no innovation in the company (0 = No).

Input constructs identify the level of use of internal and external resources. Output constructs assess the development or introduction of new products and processes by the company and the level of this innovation (i.e. company, market or world). Outcome constructs verify the impacts of these innovations, i.e. whether products were placed in the market by expanding the mix of existing products, increasing product quality, market share, process flexibility and reducing costs. The outcomes measure the effects on performance as the introduction of innovations may not be transformed into positive product, market and operational impacts.

Results

Descriptive statistics

[Supplementary material table 2](#) shows the main estimated parameters of the variables. Among the input variables, there is a significant use of employee training (*TRAIN*) oriented to the company's development of products and/or processes and innovative activities as well as the acquisition of equipment (*EQUIP_ACQ*) specifically for implementing new or improved products or processes. On the other hand, acquisition of external R&D (*R&D_ACQ*) for development of new products or processes and acquisition of technical and scientific knowledge (*KNOW_ACQ*), such as purchase of licenses for patent exploitation, were the least used inputs.

With regard to product innovation outputs, the higher the degree of innovation, the lower its occurrence. Worldwide innovations (*PDI_WORLD*) were rare (mean = 0.038), whereas product innovations already in the market (*PDI_FIRM*) were more frequent (mean = 0.495). The most frequent process innovations were related to production methods (*PCI_METH*), which required relatively less investment rather than innovations in equipment (*PCI_EQUIP*) and logistic systems (*PCI_LOG*). As for the degree of innovation, the most frequent innovations were new only within the company (*PCI_FIRM*) (mean = 0.815), whereas innovations new for the entire industrial sector (*PCI_SEC*) were less frequent (mean = 0.136).

Model assessment

This model, which presents both formative (*int_INPUTS*, *ext_INPUTS*, *prod_OUTPUT* and *proc_OUTPUT*) and reflective constructs (*prod_OUTCOME*, *mkt_OUTCOME* and *opp_OUTCOME*) undergoing different validation steps, requires validation through measurement and assessment of its structure.

The validation of reflective and formative constructs is shown in [Supplementary material table 3](#) and [Supplementary material table 4](#). Reflective constructs are validated by internal consistency (composite reliability – CR > 0.70), convergent validity (outer loading > 0.40 and average variance extracted – AVE > 0.50) and discriminant validity (cross-loadings and Fornell–Larcker criterion) (Hair, Hult *et al.*, 2017). Formative constructs are validated by collinearity (variance inflation factor – VIF < 5.0) and significance and relevance (outer weights significant at *p*-value < 0.05 or outer loadings > 0.70). In this context, the variable TRAIN did not meet the criteria and was removed from the model.

With regard to internal inputs (*int_INPUTS*), the greatest contribution to the construct was attributed to internal R&D activities (outer weight for *INT_R&D* = 0.780), followed by activities related to marketing and launch of product innovations (outer weight for *COM_ACTIV* = 0.393). On the other hand, there was a low contribution by activities related to production and distribution of innovations (outer weight for *OTHER_PREP* = 0.160). As for external inputs (*ext_INPUTS*), the variable contributing most to the construct was the acquisition of equipment (outer weight for *EQUIP_ACQ* = 0.791), followed by software acquisition (outer weight for *SOFT_ACQ* = 0.453). External acquisition of R&D (outer weight for *R&D_ACQ* = 0.163) and other external knowledge acquisition (outer weight for *KNOW_ACQ* = 0.061) showed little contribution in the construct.

Product innovation output (*prod_OUTPUT*) had two main variables: introduction of new or significantly improved products for the company (*PDI_FIRM* outer weight = 0.840) and introduction of new or significantly improved products in the national market (outer weight for *PDI_NAT* = 0.655). The variable identifying product innovations at the global level (*PDI_WORLD*) had no major contribution due to a very small number of companies carrying out this innovation.

Process innovation output (*proc_OUTPUT*) is composed of two groups of variables: three variables (*PCI_METH*, *PCI_LOG* and *PCI_EQUIP*) refer to the scope of process innovation, whereas the other two (*PCI_FIRM* and *PCI_SEC*) refer to the degree of novelty. The novelty variables make relatively little contribution to the formation of constructs. On the other hand, there is a greater contribution to the formation of the *proc_OUTPUT* construct by innovations related to manufacturing methods (outer weight for *PCI_METH* = 0.677), followed by the introduction of equipment (outer weight for *PCI_EQUIP* = 0.469), whereas logistic system innovation (*PCI_LOG*) was not very influential (outer weight = 0.179).

By analyzing the variables related to product outcomes, it is noticed that a mix of goods and services offered (*PROD_RANGE*) was the variable with the greatest explained variance (outer loading = 0.974), whereas product quality (*PROD_QUAL*) had a low proportion of explained variance (outer loading = 0.445). The most relevant variable to the market

outcome construct was the opening of new markets (outer loading for *NEW_MKT* = 0.912). This was followed by an increase in market share (outer loading for *MKT_INCRE* = 0.722), whereas maintenance of market share (*MKT_MAINT*) was the indicator with the lowest rate of variance explained (outer loading = 0.582). As for the operational performance outcomes, there was a great relevance of production capacity (outer loading for *MANUF_CAP* = 0.824), flexibility (outer loading for *MANUF_FLEX* = 0.780) and reduction of production costs (outer loading for *MANUF_COST* = 0.822) and labor costs (outer loading for *LAB_COST* = 0.816). However, the reduction of raw material consumption (*RM_CONSUM*) had a low influence on the construct (outer loading = 0.573).

The assessment of the structural model comprised two steps: verification of inner collinearity, where the model had VIF <5.0 for all values, and validation of path coefficients by using the bootstrapping procedure (Supplementary material table 5).

Supplementary material figure 2 shows the results of the structural model analysis.

Internal efforts (*int_INPUT*) have a positive and significant influence on the development of product innovations (*prod_OUTPUT*: $\beta = 0.460$), being relatively more substantial than the impact on the performance of process innovation (*proc_OUTPUT*: $\beta = 0.085$). However, despite the low impact, this relationship is positive and significant. Therefore, there is evidence to support H1a and H1b.

External resources (*ext_INPUT*) have a considerable and statistically significant influence ($\beta = 0.476$) on the development of process innovations (*proc_OUTPUT*), including a slightly negative relationship ($\beta = -0.108$) with product innovation (*prod_OUTPUT*). As external resources contribute to process innovations, one can state that H1d is supported. However, there is no empirical evidence to support H1c.

The outcomes related to product variety and quality (*prod_OUTCOMES*) are influenced by both types of innovation, thus supporting H2a and H2b. However, product outputs (*prod_OUTPUT*) are clearly more influential ($\beta = 0.687$) than process outputs (*proc_OUTPUT*) ($\beta = 0.063$). This was already expected, despite the results showing that Brazilian companies are not only improving existing products, which would not generate an increase in the mix, but also expanding the products offered and their quality through innovation.

The relationships of product and process outputs with market outcomes were found to be statistically significant for both but had low intensity with process outputs ($\beta = 0.123$) and high intensity with product outputs ($\beta = 0.519$). Thus, H2c and H2d are supported.

The relationships of *proc_OUTPUT* and *prod_OUTPUT* with operational performance (*opp_OUTCOMES*) had different behaviors compared to other outcomes, being more pronounced with process outputs ($\beta = 0.407$) and slightly negative with product outputs, despite being statistically significant ($\beta = -0.107$). Thus, hypothesis H2f is supported, but there is no empirical evidence to support H2e. In addition to the direct relationships in the structural model, it is possible to perform an analysis of the indirect relationships mediated by outputs (Supplementary material table 6).

The analysis of indirect effects between constructs of inputs and outcomes through innovation outputs is discussed below, which is associated with research question RQ3. The most intense indirect effects are between internal inputs (*int_INPUT*) and product outcomes (*prod_OUTCOMES*) (0.322), in which much of the relationship (0.316) is mediated by the product output. Another indirect effect is caused by the impact of internal inputs on market outcomes (0.250) in large part as a result of product output (0.239), showing that internal inputs positively influence product outputs. This generates positive results in terms of product variety and quality, as new markets are opened and market share is increased. Mediation in the process output is almost non-existent in relationships of internal inputs with product and market outcomes because the relationship between internal input and process output is low (0.085).

In the relationship between external inputs and operational performance, the indirect effect is more significant when mediated by process output (*proc_OUTPUT*) (0.194), which generates benefits related to production capacity, labor costs and flexibility.

There are two negative indirect effects, namely low intensities between internal inputs and operational performance (−0.014) and between external inputs and product outcomes (*prod_OUTCOMES*) (−0.045). These effects demonstrate that internal inputs do not support a positive effect, being statistically significant on operational performance, and the same is true for the indirect relationship between external inputs and product outcomes.

The determination coefficients (R^2) indicate predictive accuracy of each construct (Hair, Matthews *et al.*, 2017). According to behavioral sciences, values of 0.02, 0.13 and 0.26 are considered, respectively, weak, moderate and substantial (Cohen, 1988). By adopting this scale, the predictive accuracy of the product ($R^2 = 0.209$) and process ($R^2 = 0.246$) outputs ranges from moderate to substantial. Product outcomes have substantial predictive accuracy, as 47.4% of the construct variance is explained by the model ($R^2 = 0.474$). Market outcomes also have substantial predictive accuracy ($R^2 = 0.283$), whereas the accuracy of operational performance is moderate ($R^2 = 0.178$).

Discussion

This study proposed ten hypotheses for the analysis of input-output-outcome relationships based on research questions objectively. Hypotheses H1a and H1b, which address the influence of internal inputs on product and process outputs, were supported. The results show that Brazilian companies are converting their internal investments into product innovations, contrary to findings of other studies on emerging markets, suggesting that internal R&D have little influence on product innovations (e.g. Goedhuys & Veugelers, 2012). A further observation was that internal R&D efforts are more focused on product technologies rather than directed toward processes. This may demonstrate that internal efforts are aimed at market rather than operational structures.

Our findings also indicate that external resources can contribute to process innovations, which are in line with Crespi and Zuniga (2012), who found that process innovation in emerging markets can be driven by acquisition strategies (H1d). Although empirical evidence supported hypothesis H1d, the same was not observed for support H1c. In addition, these results reinforce the fact that Brazilian companies are having a positive impact on product innovation based on their investments in internal R&D, but they are dependent on acquisitions of external R&D and knowledge for the development of processes. Brazilian industrial policy has stimulated the acquisition of foreign knowledge and equipment (Santos *et al.*, 2018). However, the results show that this approach can better favor process innovation, in addition to giving rise to a passive attitude toward operational improvement strategies for innovative efforts (Orsi *et al.*, 2019).

Therefore, although the search for external resources generates greater value for process innovation, our findings suggest that internal investments have generated better results for product innovation. This result may indicate priorities to be pursued by companies to organize their resources (tangible and intangible) in order to obtain competitive advantage in the environment in which they operate.

According to empirical evidence supporting hypotheses H2a and H2b, product outcomes are influenced by both product and process innovations, with the former having a higher level of impact. Product outcomes involve quality improvement and expansion into a variety of products being offered. Although an increase in product variety may be impacted with the implementation of product innovations, this observation should be made with caution as product innovations may be incremental or a given innovation may only replace its predecessor rather than increasing the product variety. Therefore, the companies studied

have sufficiently implemented the improvement of their products to the point in which no previous products are replaced.

The relationship of product and process outputs with market outcomes presented results similar to those of product outcomes, meaning that hypotheses H2c and H2d were supported. Product innovations within the company and in the national market were influential in expanding new markets and increasing the market share. Our findings show that despite the market being made up of consumers with lower *per capita* income and limited access to goods and services, product innovations are meeting the customer needs by allowing companies to maintain or enter into new markets. The companies are also achieving market outcomes through process innovation. Process innovations have a positive impact on market share results in Brazilian companies. This result corroborates with similar findings on the positive relationship of both product and process outputs with market outcomes in emerging markets (e.g. Canh *et al.*, 2019).

As for operational performance outcomes, the relationship with process outputs was positive and statistically significant, which supports hypothesis H2f. Process outputs, and indirectly external inputs, lead to improvements in operational performance and consequently reinforce the role of acquisition in organizational performance, as highlighted by other authors (e.g. Carvache-Franco, Gutierrez, Guim-Bustos, & Carvache-Franco, 2020; Charmjuree *et al.*, 2021). This may indicate that companies are making management efforts to exploit acquired knowledge in order to overcome potential barriers.

On the other hand, product innovations had a negative relationship with operational performance outcomes, thus not supporting hypothesis H2e. This result is contrary to previous studies on Indian companies (Paily, 2018) and Brazilian companies (Tironi & Cruz, 2008), which showed that product innovations raised productivity immediately, whereas process innovations negatively affected productivity. This may have occurred in our sample (PINTEC) because the efforts to develop new products can adversely affect operational performance in the short term, which increases production costs and decreases capacity and productivity as a result of the adaptations required for new products. However, it is important that future studies investigate these findings further.

These findings also present distinct trajectories of the impacts on outcomes due to the effect of product and process innovations, which is in line with other studies (e.g. Vaona & Pianta, 2008). While product innovations mainly impact the quality and variety of products and the potential growth of market share, process innovations influence the efficiency of production processes and reduce costs through new technologies.

Conclusions

The proposal of this model and the results obtained contribute to the theory in innovation management and public policies for innovation, especially in emerging markets. It was possible to identify and analyze relationships of product and process innovation efforts with product, market and operational outcomes. The results are particularly relevant, given the Brazilian case can serve as a reference for other emerging countries.

The main results of this study show that internal investments have generated better results for product innovation, while the search for external resources generates greater value for process innovation. Product innovations are favored by more in-house resources (e.g. R&D and commercial activities), whereas process innovations are favored by external resources (e.g. acquisition of machines, equipment and software). Market outcomes are positively impacted by both product and process innovations. The quality and variety of products are improved through investment in internal R&D, mediated by product innovation, whereas external acquisition of machines and equipment impacts operational outcome, mediated mainly by process innovation. When observing the market outcome,

encompassing market share and new markets, there is an impact of investment in internal R&D, mediated by product innovation.

This study has implications for managers and policymakers. For managers, the results presented can improve the decision-making process on investments in internal or external resources for innovation. The implications are also related to the identification of the main inputs to foster innovation, such as internal R&D and acquisition of equipment for internal and external inputs, respectively. Furthermore, the results can also support companies and policymakers in the decision-making process regarding investments in innovation, as internal inputs tend to favor product innovations as well as external inputs may favor process innovations. The results indicated that managers and policymakers can stimulate innovation outcomes by eliminating barriers and encouraging product innovations to create even better products and improve market performance and process innovations to achieve operational improvements. In order to improve innovation performance, the results of this study can also guide public innovation policies, such as those for open innovation and strengthening of innovation ecosystems.

This study has limitations, which should be acknowledged. One limitation is related to selection bias. Although the use of a comprehensive and official database (i.e. PINTEC) has several positive points, given the robustness of the results and sample size, the generalization of results is limited. Another limitation is that despite the benefits of using variables measured by the users' perceptions, such an approach poses challenges for comparison with previous studies. Therefore, objective measures could provide more precision in the results. The variables studied were limited to their existence in the PINTEC database and the use of a greater number of variables could enrich the analysis.

There are several possibilities for future studies. One of them is related to the comparison of the results of this study with those from other countries, mainly considering both developed and developing ones. There is also an opportunity to compare different types of companies by sector and size to guide public policies and management decisions. Analyses of other relationships could be carried out, for example, by analyzing the direct effect between inputs and outcomes to broadly verify the mediating effect of the product and process innovations (which was a limitation of the present study). Other opportunities for future studies might address the following questions: Are innovation tax incentive policies, which are traditional in countries like Brazil, more effective for which innovation input-output-outcome paths? Is the use of external R&D resources acquired from partners such as universities and research centers more effective in terms of impacts on innovation outcomes than resources acquired from other companies?

References

- Al-Jobor, G. S., Al-Weshah, G. A., Al-Nsour, M., Abuhasshesh, M., & Masa'deh, R. (2020). The role of product innovation and flexibility as competitive priorities in gaining market share: Empirical evidences from Jordanian manufacturing SMEs. *International Journal of Systematic Innovation*, 6(2), 20–35.
- Bianchini, S., Pellegrino, G., & Tamagni, F. (2018). Innovation complementarities and firm growth. *Industrial and Corporate Change*, 27(4), 657–676. doi: [10.1093/icc/dty008](https://doi.org/10.1093/icc/dty008).
- BRAZIL (2016). Instituto Brasileiro de Geografia e Estatística, *Pesquisa Industrial de Inovação Tecnológica* (PINTEC, Year 2014).
- Cabagnols, A., & Bas, C. L. (2002). Differences in the determinants of product and process innovations: The French case. In A. Kleinknecht, & P. Mohnen (Eds), *Innovation and Firm Performance: Econometric Explorations of Survey Data* (pp. 12–149). Palgrave, New York.

- Canh, N. T., Liem, N. T., Thu, P. A., & Khuong, N. V. (2019). The impact of innovation on the firm performance and corporate social responsibility of Vietnamese manufacturing firm. *Sustainability*, 11(13), 3666. doi: [10.3390/su11133666](https://doi.org/10.3390/su11133666).
- Carvache-Franco, O. D., Gutierrez, G., Guim-Bustos, P., Carvache-Franco, M., & Carvache-Franco, W. (2020). Effect of R&D intensity on the innovative performance of manufacturing companies. Evidence from Ecuador, Peru and Chile. *International Journal of Innovation Science*, 12(5), 509–523. doi: [10.1108/ijis-04-2020-0046](https://doi.org/10.1108/ijis-04-2020-0046).
- Charmjuree, T., Badir, Y. F., & Safdar, U. (2021). External technology acquisition, exploitation and process innovation performance in emerging market small and medium sized enterprises: The moderating role of organizational slack. *European Journal of Innovation Management*, 25(2), 545–566. doi: [10.1108/EJIM-07-2020-0263](https://doi.org/10.1108/EJIM-07-2020-0263).
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Colombo, D. G., & Cruz, H. N. (2023). Impact assessment of innovation tax incentives in Brazil. *Innovation and Management Review*, 20(1), 28–42. doi: [10.1108/inmr-11-2020-0167](https://doi.org/10.1108/inmr-11-2020-0167).
- Crespi, G., & Zuniga, P. (2012). Innovation and productivity: Evidence from six Latin American countries. *World Development*, 40(2), 273–290. doi: [10.1016/j.worlddev.2011.07.010](https://doi.org/10.1016/j.worlddev.2011.07.010).
- Dall Corte, V. F., Dabdab, P., & Stiegert, K. (2015). Wheat industry: Which factors influence innovation?. *Journal of Technology Management and Innovation*, 10(3), 11–17. doi: [10.4067/S0718-27242015000300002](https://doi.org/10.4067/S0718-27242015000300002).
- Dervitsiotis, K. N. (2010). A framework for the assessment of an organisation's innovation excellence. *Total Quality Management*, 21(9), 903–918. doi: [10.1080/14783363.2010.487702](https://doi.org/10.1080/14783363.2010.487702).
- Franco, E., Ray, S., & Ray, P. K. (2011). Patterns of innovation practices of multinational-affiliates in emerging economies: Evidences from Brazil and India. *World Development*, 39(7), 1249–1260. doi: [10.1016/j.worlddev.2011.03.003](https://doi.org/10.1016/j.worlddev.2011.03.003).
- Frank, A. G., Cortimiglia, M. N., Ribeiro, L. L. D., & Oliveira, L. S. (2016). The effect of innovation activities on innovation outputs in Brazilian industry: Market-orientation vs technology-acquisition strategies. *Research Policy*, 45(3), 577–592. doi: [10.1016/j.respol.2015.11.011](https://doi.org/10.1016/j.respol.2015.11.011).
- Goedhuys, M., & Veugelers, R. (2012). Innovation strategies, process and product innovations and growth: Firm-level evidence from Brazil. *Structural Change and Economic Dynamics*, 23(4), 516–529. doi: [10.1016/j.strueco.2011.01.004](https://doi.org/10.1016/j.strueco.2011.01.004).
- Gonçalves, E., Lemos, M. B., & de Negri, J. A. (2008). Determinants of technological innovation in Argentina and Brazil. *CEPAL Review*, 2008(94), 71–95. doi: [10.18356/9090ac45-en](https://doi.org/10.18356/9090ac45-en).
- Guarascio, D., & Tamagni, F. (2019). Persistence of innovation and patterns of firm growth. *Research Policy*, 48(6), 1493–1512. doi: [10.1016/j.respol.2019.03.004](https://doi.org/10.1016/j.respol.2019.03.004).
- Guimarães, J. C. F., Severo, E. A., Campos, D. F., El-Aouar, W. A., & de Azevedo, F. L. B. (2020). Strategic drivers for product and process innovation: A survey in industrial manufacturing, commerce and services. *Benchmarking: An International Journal*, 27(3), 1159–1187.
- Gupta, A. K. (2021). Innovation dimensions and firm performance synergy in the emerging market: A perspective from dynamic capability theory and signaling theory. *Technology in Society*, 64, 101512.
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017a). *A primer on partial least squares structural equation modeling (PLS-SEM)*. Thousand Oaks, CA: SAGE Publications.
- Hair, J. F., Matthews, L. M., Matthews, R. L., & Sarstedt, M. (2017b). PLS-SEM or CB-SEM: Updated guidelines on which method to use. *International Journal of Multivariate Data Analysis*, 1(2), 107–123. doi: [10.1504/ijmda.2017.10008574](https://doi.org/10.1504/ijmda.2017.10008574).
- Haneda, S., & Ito, K. (2018). Organizational and human resource management and innovation: Which management practices are linked to product and/or process innovation?. *Research Policy*, 47(1), 194–208. doi: [10.1016/j.respol.2017.10.008](https://doi.org/10.1016/j.respol.2017.10.008).

- Hashi, I., & Stojcic, N. (2013). The impact of innovation activities on firm performance using a multi-stage model: Evidence from the Community Innovation Survey. *Research Policy*, 42(2), 353–366. doi: [10.1016/j.respol.2012.09.011](https://doi.org/10.1016/j.respol.2012.09.011).
- Hervas-Oliver, J. L., Sempere-Ripoll, F., & Boronat-Moll, C. (2014). Process innovation strategy in SMEs, organizational innovation and performance: A misleading debate?. *Small Business Economics*, 43(4), 874–886. doi: [10.1007/s11187-014-9567-3](https://doi.org/10.1007/s11187-014-9567-3).
- Janger, J., Schubert, T., Andries, P., Rammer, C., & Hoskens, M. (2016). *The EU 2020 innovation indicator*. Centre for European Economic Research. (Paper No. 16-072).
- Kahn, K. B. (2018). Understanding innovation. *Business Horizons*, 61(3), 453–460. doi: [10.1016/j.bushor.2018.01.011](https://doi.org/10.1016/j.bushor.2018.01.011).
- Kalyar, M. N., Shoukat, A., & Shafique, I. (2019). Enhancing firms' environmental performance and financial performance through green supply chain management practices and institutional pressures. *Small Business Economics*, 34(3), 339–353.
- Kanneble, S., Sekkel, J. V., & Araújo, B. C. (2020). Economic performance of Brazilian manufacturing firms: A counterfactual analysis of innovation impacts. *Sustainability Accounting Management and Policy Journal*, 11(2), 451–476. doi: [10.1108/SAMPJ-02-2019-0047](https://doi.org/10.1108/SAMPJ-02-2019-0047).
- Karabulut, A. T. (2015). Effects of innovation types on performance of manufacturing firms in Turkey. *Procedia-Social and Behavioral Sciences*, 195, 1355–1364. doi: [10.1016/j.sbspro.2015.06.322](https://doi.org/10.1016/j.sbspro.2015.06.322).
- Lizarelli, F. L., & Toledo, J. C. (2015). Identification of relations between continuous improvement and innovation of products and processes: A systematic literature review. *Gestão and Produção*, 22(3), 590–610. doi: [10.1590/0104-530x1227-14](https://doi.org/10.1590/0104-530x1227-14).
- Lumiste, R., & Kilvits, K. (2004). Estonian manufacturing SMEs innovation strategies and development of innovation networks. In *13th Nordic Conference on Small Business Research* (pp. 10–12). Norway: University of Oslo.
- Medda, G. (2020). External R&D, product and process innovation in European manufacturing companies. *Journal of Technology Transfer*, 45, 339–369.
- Mondéjar-Jiménez, J., Segarra-Oña, M., Peiró-Signes, Á., Payá-Martínez, A. M., & Sáez-Martínez, F. J. (2015). Segmentation of the Spanish automotive industry with respect to environmental orientation of firms: Towards an ad-hoc vertical policy to promote eco-innovation. *Journal of Cleaner Production*, 86, 238–244. doi: [10.1016/j.jclepro.2014.08.034](https://doi.org/10.1016/j.jclepro.2014.08.034).
- Murovec, N., & Prodan, I. (2009). Absorptive capacity, its determinants, and influence on innovation output: Cross-cultural validation of the structural model. *Technovation*, 29(12), 859–872. doi: [10.1016/j.technovation.2009.05.010](https://doi.org/10.1016/j.technovation.2009.05.010).
- Orsi, C. E., Neuberger, D., & Cário, S. A. F. (2019). Características dos processos inovativos do setor industrial do Brasil e da região sul 2006-2014: análise sob perspectiva teórica neoschumpeteriana. *Textos de Economia*, 22(1), 32–58. doi: [10.5007/2175-8085.2019v22n1p32](https://doi.org/10.5007/2175-8085.2019v22n1p32).
- Paily, G. (2018). Innovation strategies, outcomes and firm performance: An analysis of firm behaviour in India's manufacturing sector. *Economics Bulletin*, 38(4), 1769–1786.
- Parisi, M. L., Schiantarelli, F., & Sembenelli, A. (2006). Productivity, innovation and R&D: Micro evidence for Italy. *European Economic Review*, 50(8), 2037–2061. doi: [10.1016/j.eurocorev.2005.08.002](https://doi.org/10.1016/j.eurocorev.2005.08.002).
- Reichstein, T., & Salter, A. (2006). Investigating the sources of process innovation among UK manufacturing firms. *Industrial and Corporate Change*, 15(4), 653–682. doi: [10.1093/icc/dtl014](https://doi.org/10.1093/icc/dtl014).
- Santos, D. F. L., Basso, L. F. C., & Kimura, H. (2018). The trajectory of the ability to innovate and the financial performance of the Brazilian industry. *Technological Forecasting and Social Change*, 127, 258–270. doi: [10.1016/j.techfore.2017.09.027](https://doi.org/10.1016/j.techfore.2017.09.027).
- Shankar, V., & Narang, U. (2019). Emerging market innovations: Unique and differential drivers, practitioner implications, and research agenda. *Journal of the Academy of Marketing Science*, 48, 1030–1052. doi: [10.1007/s11747-019-00685-3](https://doi.org/10.1007/s11747-019-00685-3).

-
- Sinha, K. K., Saunders, C., & Raby, S. O. (2022). Cooling off innovation hotspots: Smaller businesses need to look wide and deep. *Journal of Business Strategy*, 44(6), 354–362. doi: [10.1108/JBS-07-2022-0124](https://doi.org/10.1108/JBS-07-2022-0124).
- Song, M., & Chen, Y. (2014). Organizational attributes, market growth, and product innovation. *Journal of Product Innovation Management*, 31(6), 1312–1329. doi: [10.1111/jpim.12185](https://doi.org/10.1111/jpim.12185).
- Tavassoli, S. (2018). The role of product innovation on export behavior of firms. *European Journal of Innovation Management*, 21(2), 294–314. doi: [10.1108/ejim-12-2016-0124](https://doi.org/10.1108/ejim-12-2016-0124).
- Tironi, L. F., & Cruz, B. D. O. (2008). Inovação incremental ou radical: há motivos para diferenciar? Uma abordagem com dados da PINTEC. *Repositório do Conhecimento do IPEA*. Available from: <https://repositorio.ipea.gov.br/handle/11058/1537>
- Vaona, A., & Pianta, M. (2008). Firm size and innovation in European manufacturing. *Small Business Economics*, 30(3), 283–299. doi: [10.1007/s11187-006-9043-9](https://doi.org/10.1007/s11187-006-9043-9).
- Vargas, N., Lloria, M. B., Salazar, A., & Vergara, L. (2022). Innovative outcome through exploration and exploitation—Enablers, barriers and industrial property. *European Journal of Management and Business Economics*, 31(1), 40–56. doi: [10.1108/ejmbe-11-2019-0213](https://doi.org/10.1108/ejmbe-11-2019-0213).
- Wang, N., Xiao, M., & Savin, I. (2020). Complementarity effect in the innovation strategy: Internal R&D and acquisition of capital with embodied technology. *The Journal of Technology Transfer*, 46(2), 459–482. doi: [10.1007/s10961-020-09780-y](https://doi.org/10.1007/s10961-020-09780-y).
- Zanello, G., Fu, X., Mohnen, P., & Ventresca, M. (2016). The creation and diffusion of innovation in developing countries: A systematic literature review. *Journal of Economic Surveys*, 30(5), 884–912. doi: [10.1111/joes.12126](https://doi.org/10.1111/joes.12126).
- Zhou, X., Cai, Z., Tan, K. H., Zhang, L., Du, J., & Song, M. (2021). Technological innovation and structural change for economic development in China as an emerging market. *Technological Forecasting and Social Change*, 167, 120671. doi: [10.1016/j.techfore.2021.120671](https://doi.org/10.1016/j.techfore.2021.120671).

Further reading

- De Negri, F. (2018). *Novos caminhos para a inovação no Brasil*. Washington, DC: Wilson Center-Interfarma.
- Hullova, D., Simms, C. D., Trott, P., & Laczko, P. (2019). Critical capabilities for effective management of complementarity between product and process innovation: Cases from food and drink industry. *Research Policy*, 48(1), 339–354. doi: [10.1016/j.respol.2018.09.001](https://doi.org/10.1016/j.respol.2018.09.001).
- Lizarelli, F. L., Toledo, J. C., & Alliprandini, D. H. (2021). Relationship between continuous improvement and innovation performance: Study in Brazilian manufacturing companies. *Total Quality Management and Business Excellence*, 32, 981–1004.
- Van Beers, C., & Zand, F. (2014). R&D cooperation, partner diversity, and innovation performance: An empirical analysis. *Journal of Product Innovation Management*, 31(2), 292–312. doi: [10.1111/jpim.12096](https://doi.org/10.1111/jpim.12096).

Supplementary material

The supplementary material for this article can be found online.

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