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Impact of Financial Investment and Technology Adoption on Operational Efficiency: Process Innovation as a Mediator in the Pharmaceutical Industry

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ABSTRACT

This study examines the impact of financial investment and technology adoption on operational efficiency in the pharmaceutical industry, with process innovation as a mediating factor. Operational efficiency is critical for pharmaceutical firms to meet regulatory requirements, reduce costs, and remain competitive in a rapidly evolving market. Drawing on Resource-Based View (RBV) and Dynamic Capabilities Theory, this research investigates how financial resources and technological advancements drive performance improvements when coupled with innovative processes. Using a quantitative research approach, data were collected from 250 professionals in the pharmaceutical industry through a structured questionnaire. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to assess direct and mediated relationships among the variables. The findings reveal that both financial investment and technology adoption significantly enhance operational efficiency, while process innovation plays a pivotal mediating role, amplifying their effects. This highlights the importance of integrating financial strategies, technology adoption, and innovative practices to achieve sustained operational excellence. Future research could explore longitudinal dynamics and extend the findings to other industries.

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1.0 Introduction

In the current world where operational efficiency can be a major determinant of market competitiveness, the pharmaceutical industry has some special challenges which emerge from the regulatory environment, increased costs, and the pressure to develop new products (Rodriguez et al., 2021). Financial investment guarantees that organizations have the required resources that are needed in the process of adopting advanced technologies; on the other hand, technology adoption allows organizations to update their operations, improve the production process and meet the new market challenges. In this regard, operational efficiency stands as one of the organizational performance measures, which focus on the most effective use of resources and minimum production of scrap (Merklinger, 2019).

Process innovation has received a lot of attention as one of the most important sources of competitiveness and efficiency, especially in industries with high demands on accuracy and standard, such as the pharmaceutical industry (López Fernández, 2021). It includes the creation of new or enhanced production or operation systems in organizations whereby problems are solved, quality enhanced and costs reduced. Through an analysis of the relationship between financial investment, technology adoption and process innovation this study aims at identifying potential avenues for enhancing the long-term operational performance of pharmaceutical manufacturing and management. Technological investment act as a tool to purchase and implement new developments in a given organization because it provides the financial strength necessary for the organization to implement new changes (Strategy, 2002). Technology adoption on the other hand allow firms to utilize resources, optimize of work flow and decision making. These variables are closely interrelated, as the presence of funds leads to the extent and the rate of technology application and, in turn, technology application lays the ground for the ongoing process enhancement. Process innovation thus moderates this relationship by connecting the two in a way that turns technological resources into real operational value (Verma, 2020).

Operational efficiency, the main outcome variable of the study, is defined as the capacity to achieve the greatest level of performance using the fewest resources. It is affected by capital investment from outside as well as initiatives from within the organization. Technological change results in step-by-step change in work practices while capital investment supports the implementation of these changes. Process innovation plays the role of a dynamic mediator that links technological capabilities to the improvement of efficiency and, therefore, acts as a bridge between these two variables. Although prior research has established the link between financial investment and technological investment on the operational performance, the mediating role of process innovation in this relationship has been researched to a limited extent particularly in the context of the pharmaceutical industry. Such factors are examined separately, without considering their interactions and interrelationships. Furthermore, the regulation and functioning of the pharmaceutical industry require special attention which has not been given enough attention in the current literature.

This research aims to fill these gaps by examining the moderating effect of process innovation in the financial investment-technology adoption-operational efficiency chain. It

underlines the importance of evaluating how these factors are interconnected and how they enhance the overall efficiency of the pharmaceutical business, a sector that is founded on the principles of accuracy, creativity, and adherence to rules. By unveiling the mechanisms by which financial resources and technology adoption lead to operational efficiency, this study presents novel insights to the literature. The study will give recommendations to the managers, policy makers and other stakeholders in the pharmaceutical industry on how to best align their financial strategies, technological changes and process innovations. Finally, this research seeks to contribute to the improvement of the operational performance in the industry in order to increase its ability to meet new challenges.

2.0 Literature Review

Financial investment has been highlighted as one of the critical performance drivers in many sectors, and the current focus has been on how it can support innovation (Battisti et al., 2020). Financial resources enable organisation to purchase latest technologies, funding for research and development and solving problems associated with operations. In the pharmaceutical industry where the cost of compliance, research, and production is very high, financial investment becomes the main factor for the strategic management of competitiveness (Siagian et al., 2021). Research has also confirmed that companies with strong financial support are in a good place to adopt new measures that enhance efficiency and effectiveness. Nevertheless, the fact that the financial resources are available is not enough; their proper allocation and utilization for the achievement of operational efficiency is equally important.

Both financial investment and technology adoption have turned out to be drivers of change that have helped firms to update and innovate in order to meet the challenges of a changing industrial environment (Bárcia de Mattos et al., 2021). Automations, data analysis, and artificial intelligence have been proven to improve efficiency, increase accuracy, and decrease spending. Technology adoption is critical for the pharmaceutical industry especially because it can help reduce time taken to produce products, enhance quality and meet legal requirements. Nonetheless, the literature indicates that technology cannot be the only determinant of operational performance improvement. However, the real value is only unlocked when such technologies are combined with other advanced procedures that help to incorporate them into the routine work (Meredith et al., 2020). This dynamics between technology adoption and process innovation clearly demonstrates that improving operational efficiency is not a simple process.

Process innovation is an important mediator that links financial investment, technology, and operation performance in the organization (Troise et al., 2021). As the process of installing new or significantly changed processes, it enables organisations to translate technological and financial assets into performance results. In the pharmaceutical industry, process innovation is a key factor in managing operational problems including the cost of production, compliance and quality of products. The literature review shows that companies that focus on process improvement are more likely to capture the value of technology and investment and thus develop a sustainable system (Troise et al., 2021). This transformative potential makes process innovation a critical element in the search for operational excellence while its role as a moderator has not been explored

enough in prior research.

The relationship between investment, technology, and process changes forms a dynamic system in which each of the three components affects and is affected by the other two (Troise et al., 2021). Financial investment provides the tools required to acquire and deploy technologies, while technology adoption generates the conditions for new processes to develop. At the same time, process innovation guarantees the efficient use of the technologies and resources to achieve these improvements. This interdependency has been recognized in previous research but the vast majority of the existing work analyses these factors as separate and does not consider their joint effect and possible mediation pathways (Cao et al., 2021). This is especially so in the pharmaceutical industry, which, due to having its own rather specific operational and regulatory environment, requires a more specific solution.

Filling these gaps calls for a better appreciation of the role of process innovation in the financial investment-technology adoption-operation efficiency relationship. Although there is literature on the direct relationship between these variables and performance, the mediating relationship has not been investigated (Magatef et al., 2023). This gap hinders the effective exploitation of investments and technological resources by organizations. In particular, the requirements of the pharmaceutical industry for precision, compliance, and innovation only strengthen the need for a more detailed discussion of the issues and trends in the sector. Through these interdependencies, this study intends to propose a conceptual model to help explain and improve the operational effectiveness of this vital sector.

The conceptual framework of this study is based on the RBV and Dynamic Capabilities Theory, which posit that firms should build and deploy resources and capabilities to generate a sustainable competitive advantage (Alcaide Ruiz, 2022). Based on the RBV, the financial investment and technology adoption are valuable and rare that can influence the organizational performance. Process innovation, on the other hand, define a dynamic capability that allows the firms to adapt these resources and refine them according to the changes in the market environment (Rogut, 2013). This configuration of resources and capabilities forms a coherent basis for analyzing the moderating effect of process innovation and how firms can attain operational efficiency by making strategic investments and adopting new technologies.

The above theoretical frameworks also find empirical support in this study because financial investment and technology adoption are key determinants of operational efficiency (Giampietri et al., 2020). However, the effect of these factors is usually moderated by other factors like process innovation. For example, it has been found that organizations that adopt technology but do not adopt innovation processes are not able to attain the expected performance. On the other hand, the firms that adopt process innovation in their strategies are likely to benefit fully from their investments (Troise et al., 2021). This is to suggest that it is high time that financial investment, technology adoption and process innovation are seen as being part of a system.

Thus, the present work focuses on the pharmaceutical industry as a specific and rather interesting object of study. This focus on precision, rules and regular improvement makes it a perfect context within which to consider the links between financial investment, the uptake of

technology and operations management (Ishak & Mohamed, 2023). Through examining these dynamics, this research seeks to meet important research questions and offer useful recommendations to the practical world. The study will not only add to the body of academic literature but will also provide useful recommendations to managers and policy makers who wish to improve operational efficiency in the pharmaceutical industry.

The hypotheses developed for the study are based on these theoretical and empirical literatures and capture the interdependence between financial investment, technology adoption, process innovation, and operational efficiency (Graziano et al., 2023). They are used to examine both direct and mediated effects and provide a complete picture of how these factors affect each other. By adopting this integrative approach, the mediating role of process innovation is examined in detail, while also filling the research gap and enhancing the understanding of operational efficiency in the pharmaceutical industry. In light of the current study and previous work, this paper presents a coherent conceptual model of the factors that affect CSR practices in different sectors (Beldzik et al., 2022).

3.0 Methodology

This research uses the quantitative research design in order to measure the variables that are associated with financial investment, technology adoption, process innovation and operational efficiency in the pharmaceutical industry. Through quantitative analysis, theses variables can be systematically analyzed and data analysis can be done through hypothesis testing. With a view of arriving at the objective findings, the study will adopt a systematic method of collecting and analyzing data with a view of establishing the direct and indirect impacts of the variables of interest. Data was collected through the use of a questionnaire developed from previous literature and research questionnaires. To enhance the validity and reliability of the constructs, the scales have been borrowed from prior research. The survey instrument has been developed to cover aspects such as financial investment, technology take up, process improvement and operational effectiveness, and all the questions are measured on a five-point Likert scale of strongly agree to strongly disagree. All these items were selected and customized for the pharmaceutical industry so that their purpose and meaning remain unaltered.

The target population is made up of professionals operating in the operational, financial, and technological positions in the pharmaceutical industry. For the purpose of this study, a total of 250 respondents were chosen to participate in the survey to increase the validity and reliability of data collected for the analysis. The number of the participants was based on the suggestion of the PLS-SEM, which is employed in this research to analyze the proposed hypothesis. This method, however, has to involve a large number of participants to make the model bulletproof and the results credible. The research uses simple random sampling to approach the participants from the target population. This sampling technique helps to eliminate possibility of sampling bias and increase the probability of the population characteristics being well represented in the sample. The sample was selected in a random manner from the list of the professionals from the pharmaceutical companies, industries, and associations, and networks. The survey was conducted electronically using emails; participants were provided with detailed information and guidelines, and undertaking

the survey was considered to be anonymous.

As the data were collected, the analysis of the data was done using SmartPLS 4, a software for conducting Partial Least Squares Structural Equation Modeling. This study used PLS-SEM since it is effective for handling research models with multiple constructs and is appropriate in exploratory research. It is particularly useful for testing mediated effects, which are of interest in this study through the lens of process innovation. First, the measurement model was evaluated to determine the reliability and validity of the constructs, and second, the structural model was tested to investigate the relationships between the variables.

The measurement model was assessed with regard to its reliability and convergent validity through the use of Cronbach's alpha, composite reliability, and AVE. The Fornell-Larcker criterion and cross-loadings were used to test discriminant validity. To this end the following steps are taken to ensure the constructs reflect the variables of interest without embarking on issues of multicollinearity. After confirming the measurement model, the structural model was used to examine the direct and indirect effects of financial investment, technology adoption, process innovation, and operational efficiency. The hypotheses were tested with the help of path coefficient, t-statistics and p-values from the bootstrapping procedure in Smart-PLS SEM. The bootstrapping procedure was used to create confidence intervals of the path coefficients in order to establish the validity of the relationships. All the ethical concerns were observed in the conduct of this research. All the participants were asked to sign a consent form before they filled the survey and they were told that their responses will be anonymous and confidential. Data were safeguarded and only the research team had the access to the data. These measures were taken in order to make sure that the research conducted in this study was ethical and that the rights and the privacy of the participants were not violated.

4.0 Findings and Results

4.1 Reliability Analysis

Table 4.1 Reliability Analysis

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Financial Investment	0.855	0.859	0.894	0.587
Operational Efficiency	0.787	0.785	0.839	0.508
Process Innovation	0.707	0.708	0.785	0.579
Technology Adoption	0.809	0.808	0.868	0.568

The table presents the reliability analysis for four different constructs: The four dimensions which are used in this research are Financial Investment, Operational Efficiency, Process Innovation, and Technology Adoption. The values show that internal consistency for each construct is reasonable and mostly high. In particular, the Cronbach's alpha, rho_A, and composite

reliability coefficients indicate that the constructs are sound and have high internal consistency. The AVE values show that the constructs have explained a good deal of the variance in the data, but there is some margin for improvement, especially regarding Operational Efficiency and Technology Adoption that have relatively lower AVE values.

Table 4.2 Validity Analysis (HTMT)

	Financial Investment	Operational Efficiency	Process Innovation	Technology Adoption
Financial Investment	0	0	0	0
Operational Efficiency	0.512	0	0	0
Process Innovation	0.362	0.454	0	0
Technology Adoption	0.279	0.451	0.375	0

The table presents the Heterotrait-Monotrait Ratio (HTMT) validity analysis for four constructs: The four strategic orientations have been identified as Financial Investment, Operational Efficiency, Process Innovation, and Technology Adoption. The diagonal values are zero because here the constructs are the same which have been compared, while the off-diagonal values give the amount of correlation between the two constructs. Lower values are preferred for the discriminant validity which means that the measures are different from each other. In sum, the study shows that the four constructs under consideration are closely related yet different within the analysis framework**.**

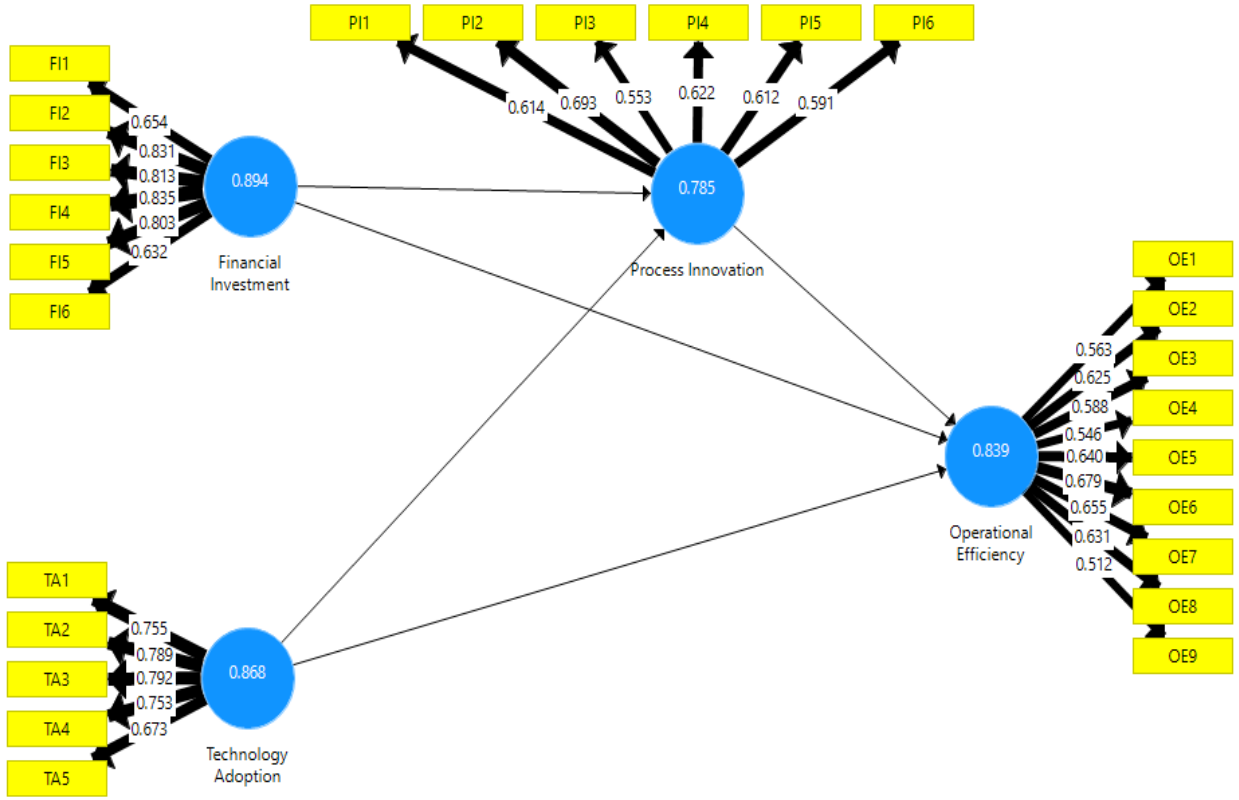

Figure 4.1: Measurement Model

4.2 Structural Equational Model

Table 4.3 Structural Equational Model (Direct Effect)

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Financial Investment -> Operational Efficiency	0.304	0.308	0.038	7.982	0
Financial Investment -> Process Innovation	0.227	0.201	0.064	3.543	0.005
Process Innovation -> Operational Efficiency	0.182	0.169	0.039	4.699	0.001
Technology Adoption -> Operational Efficiency	0.287	0.297	0.031	9.31	0
Technology Adoption -> Process Innovation	0.238	0.242	0.033	7.174	0

As presented in the model, the direct effects of financial investment, technology adoption, process innovation, and operational efficiency are captured by the structural equation model. Both operational efficiency and process innovation are improved by financial investment, which underlines the dual function of the latter. Also, technology adoption enhances operation efficiency and encourage the evolution of processes which is why it is deem as a catalyst for both technological and operation change. Furthermore, the results of process innovation are positively associated with operational efficiency, which implies that implementing new processes leads to better performance results. In conclusion, the model highlights the direct and indirect relationships between financial and technological resources and operations performance**.**

Table 4.4: Mediation Analysis

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Financial Investment -> Process Innovation -> Operational Efficiency	0.041	0.033	0.01	4.112	0.002
Technology Adoption -> Process Innovation -> Operational Efficiency	0.043	0.041	0.011	3.963	0.003

The mediation analysis in Table 4.4 shows that both financial investment and technology adoption significantly contribute to enhancing operational efficiency through process innovation. This suggests that process innovation acts as a crucial intermediary, linking these factors to improved operational outcomes. The results highlight the importance of investing in financial

resources and adopting new technologies to drive innovation processes, ultimately leading to greater efficiency in operations.

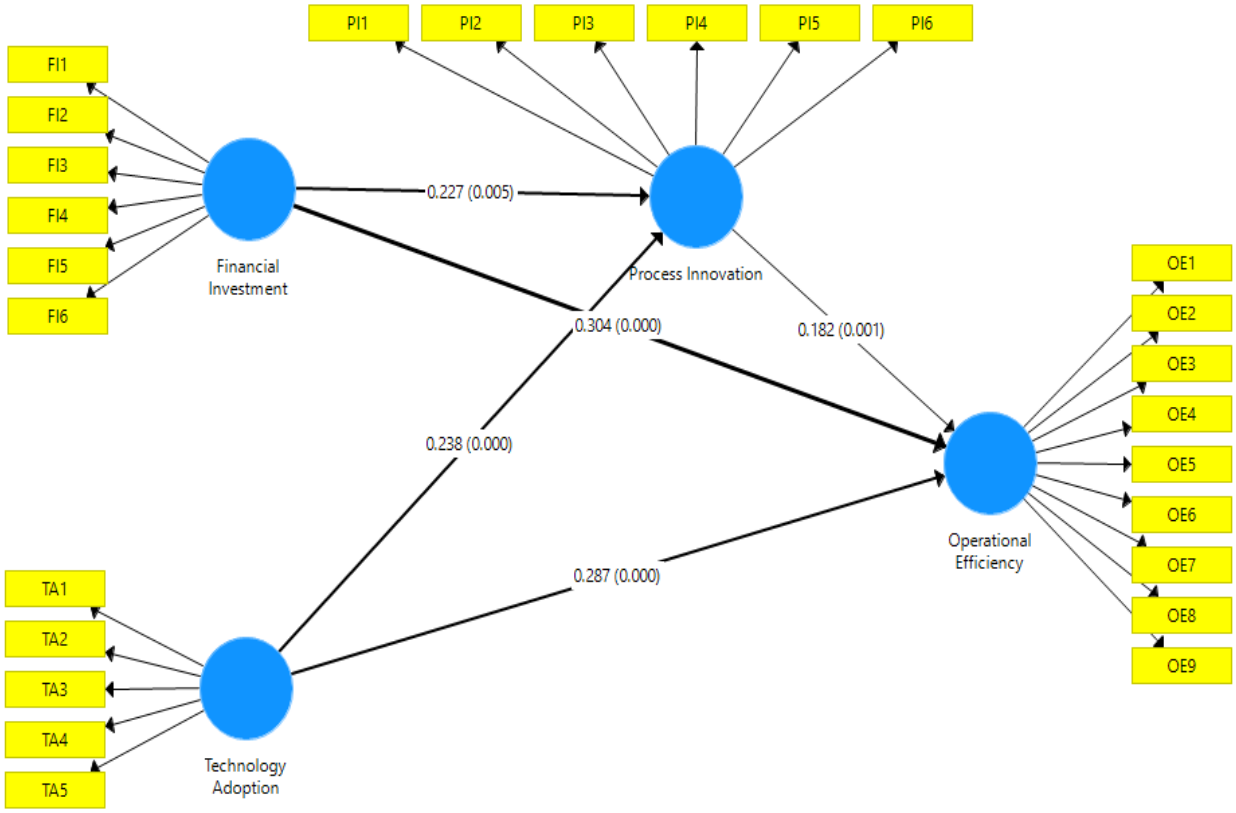

Figure 4.2: Structural Equational Model

5.0 Discussion and Conclusion

The current study's conclusions underscore the importance of financial investment in technology and process improvements in increasing the efficiency of pharmaceutical organizations. The quantitative findings show that financial investment enhances OP through the suggested model, thus affirming the proposition that organizations' financial management is a key driver of growth and performance (Nasi, 2020). This way, financial investment helps pharmaceutical companies to buy better equipment, improve their production and meet the required standards which are important for good performance. These results are consistent with the RBV theory that holds that financial resources are valuable organizational assets that organizations can use to achieve competitive advantage (Anning & Wang, 2020). Also, the study finds out that technology adoption has a positive impact on operational efficiency. This finding supports the notion that applying state of the art technologies in the pharmaceuticals industry including automation, data analysis and artificial intelligence has the potential of revolutionizing the industry.

Technology adoption not only increases efficiency and efficiency but also increases the organization's ability to meet the regulatory requirements which is crucial within the pharmaceutical industry. However, the study also supports the proposition that the effects of technology adoption on operational efficiency are magnified when accompanied by process change. This research supports the notion that technology should be integrated with other best

practices in order to achieve maximum benefits. The findings of the current study reveal that process innovation acts as a mediator in the present research. The findings show that process innovation acts as a mediator and helps to transfer positive effects of the financial investment and technology use into operations. This finding is in concordance with Dynamic Capabilities Theory that postulates that organizations need to develop and integrate new resources and capabilities to sustain their competitive standing.

This paper argues that through process innovation, pharmaceutical firms can enhance the ways in which they manufacture their products, cut costs, and enhance the quality of their products to increase their organizational effectiveness. This mediating effect also points to the interdependence of the variables in the model and the importance of an integrated approach to resources, technology and processes. These findings of this study have important theoretical and practical implications. Overall, theoretically the study contributes to knowledge of the inter-relationships between financial investment, technology adoption, and process innovation and their impact on operation efficiency. Thus, by including process innovation in the model as a mediating factor, this work fills the research gap and offers a more complex view of the factors that affect operational efficiency.

In practical terms, the results give specific recommendations to managers in the pharmaceutical industry. In order to optimize its performance, a company should make a comprehensive plan, which involves both financial resources, technology and the processes that are used in the organization (Organization, 2021). This approach guarantees optimal resource use, coherent integration of technologies into processes, and, most importantly, concentration on improvement. Nevertheless, the current study has several limitations that are identified as follows. First, the cross-sectional design of the study means that it is not possible to make conclusions that are causal in nature (Tran et al., 2020). Future work could overcome this limitation by using longitudinal designs to analyze changes in these relationships overtime. Second, although the study is based on the pharmaceutical industry, the results cannot be taken as fully applicable to other industries. Further research could be made on cross industry comparisons to enhance the understanding of the part of process innovation in different operational environments (Sang et al., 2020). Finally, there is the issue of response bias due to the use of self- administered questionnaires and to reduce this, only validated scales were used and the participants were assured of the anonymity of their responses

Muhammad Bilal: Problem Identification and Theoretical Framework
Najib Ullah Khan: Data Analysis, Supervision and Drafting
Furqan Sadiq: Methodology and Revision

Conflict of Interests/Disclosures

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