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PHARMA SUPPLY CHAIN RESILIENCE. A SYSTEMATIC REVIEW

Balázs Bence Dienes[1], Dejsi Qorri[2], János Felföldi[3] †

[1,2,3]Department of Logistics Management, Institute of Rural Development and Functional Management, Faculty of Economics and Business, University of Debrecen, Hungary

[1]dienes.balasz@econ.unideb.hu
[2]dejsi.qorri@econ.unideb.hu
[3]felfoldi.janos@econ.unideb.hu

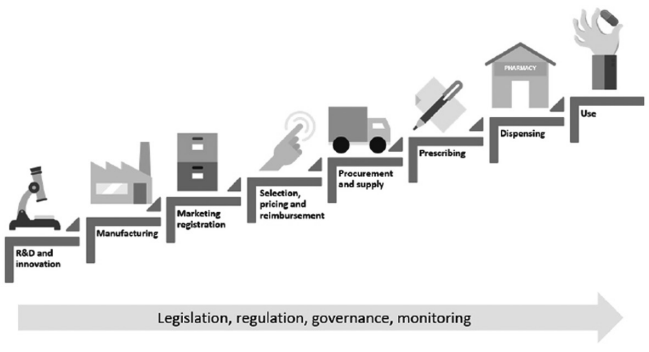
Abstract: *This study offers a thorough exploration of critical consideration of resilience in pharmaceutical supply chains, aiming to provide a comprehensive overview of the existing literature on this subject. Given the increasing globalization, regulatory complexities, and disruptions, the pharmaceutical industry encounters unique challenges in maintaining the business continuity of supply chains. Design/Methodology/Approach: We conducted a systematic analysis of 41 documents, including articles, reviews, and conference papers, employing bibliometric methods to visualize the dataset. Findings: Our findings indicate a notable increase in literature in recent years, particularly concerning risk mitigation strategies, collaboration among supply chain stakeholders, and investments in technology-driven solutions for resilience in pharmaceutical supply chains. Furthermore, we have identified several research directions. This review emphasizes the necessity for ongoing scholarly efforts aimed at fostering pharmaceutical supply chains resilience given the post-COVID-19 situation with goal of ensuring the uninterrupted availability of essential medications to patients worldwide.*

Keywords: *pharma, resilience, supply chanis, bibliometrics, review*
(JEL code: R4)

INTRODUCTION

In the pharmaceutical business, where a continuous and dependable supply of drugs is important to public health, the notion of supply chain resilience is critical. The ongoing distribution of essential medications is dependent on pharmaceutical firms' capacity to properly negotiate numerous interruptions, such as natural catastrophes, alterations to legislation, and worldwide medical emergencies (NIAZ and NWAGWU, 2023). As presented in Figure 1, the phases of a pharmaceutical value chain are R&D and innovation, manufacturing, marketing, registration, procurement and supply, prescription, dispensing and use. Meanwhile, the entire value chain is regulated, monitored, governed and legislated (United Nations Office of Drugs and Crimes).

Figure 1. The Pharmaceutical Value Chain



Source: United Nations (UN)

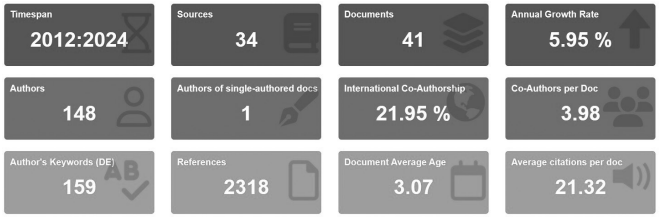
Supply chain resilience is critical to reducing the effect of these issues, ensuring that patients continue to have access to life-saving medicaments when they are most needed (ALKHOURI, 2024). Furthermore, recognizing the importance of resilience in pharmaceutical supply chains, researchers, governments, and industry stakeholders have increased their focus on understanding and improving this component of supply chain management (PATEL, 2023). This study will look into the relevance of doing a bibliometric review to examine existing research on resilience in pharmaceutical supply chains. By summarizing and critically reviewing a wide range of academic publications, we want to provide insights into current research interests, theoretical frameworks, empirical findings and emerging trends in this field. This study also aims to suggest topics for additional exploration and give insights that can help improve pharaceutical industry decision-making and policy-making. Our study describes how we gather materials and use the bibliometric method in Material

and Methods, then followed by providing the results in the Results and Discussion section using a Wordcloud, Keywords of Co-occurrence network, and thematic mapping. Moreover, the findings are then critically evaluated. Finally, conclusions are derived from the analysis

MATERIALS AND METHODS

We performed a thorough bibliometric study utilizing the Scopus database, which contains a wide range of scholarly literature from several domains, including pharmaceutical supply chains. Our search strategy involved identifying relevant scholarly works by employing the keywords: "supply chain resilience" AND "pharmaceutical" OR "pharma". More detailed information is presented in Figure 2. Then by using biblioshiny package (ARIA and CUCCURULLO, 2017), we analyzed the articles. Detailed information regarding the retrieved scholarly publications is presented in Figure 2. We obtained a total of 41 papers from 2012 to 2024. 34 (thirty-four) of these documents were derived from scholarly journals, 3 (three) from book series, 3 (three) from conference proceedings, and 1 (one) from a trade journal. The overall annual growth rate amounts to 5.95%. Method used to analyze the dataset is bibliometric analysis, which visualizes the current research environment (ARIA and CUCCURULLO, 2017) concerning pharmaceutical supply chain resilience, by assessing and analyzing a large body of scholarly publications. Bibliometric analysis is a powerful tool in identifying trends, patterns, and gaps in the current literature.

Figure 2. Information about dataset



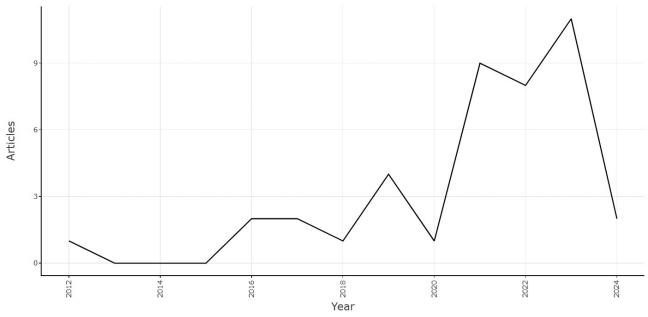
Source: Authors' work

RESULTS AND DISCUSSION

As depicted in Figure 3, there was a decline in research activity on the topic from 2012 to 2013, followed by a period from 2013 to 2015 where no scholarly work was identified. However, research on the topic experienced growth after 2015, with a noticeable increase in scholarly activity. It is evident that the topic gained popularity among scholars particularly after 2020. This was influenced significantly by COVID-19, which is further supported in Figure 4, where authors emphasize the keywords 'COVID-19' and 'pharmaceutical industry'.

As visualized in Figure 4, the COVID-19 pandemic highlighted the "complexity", "capability", and "chain resilience" of companies in pharmaceutical industry. Moreover, disruptions affected a variety of areas, including "inventory management", "advanced event processing", and "demand planning". Keywords such as "big data", "internet of things", "digital supply chains", and "decision support systems" and "augmented and virtual reality", "blockchain technology" were used to demonstrate the critical role of technology breakthroughs in improving supply chain resilience.

Figure 3. Annual Scientific Production



Source: Authors' work

Figure 4. Word Cloud with Authors' Keywords

Source: Authors' work

Furthermore, Figure 5 depicts the authors' keywords network. The image is divided into two categories: the blue network focuses on the operational elements of the drug industry, with an emphasis on humans. Meanwhile, the red network emphasizes the supply resilience.

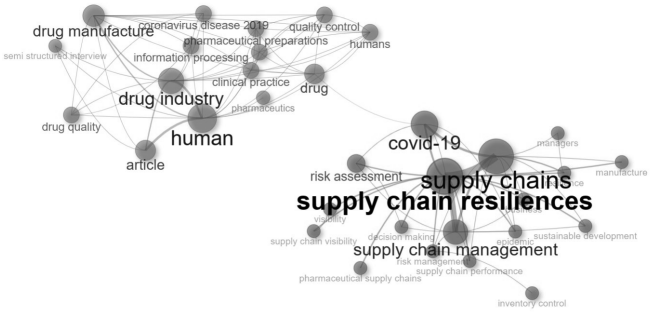
The formulations and compositions of medicinal products developed by pharmaceutical companies for medical use are known as pharmaceutical preparations. (GIBSON, 2001) Quality control is an important part of the manufacturing process because it ensures that pharmaceutical preparations meet strict quality criteria and a thorough testing and analysis of raw materials, intermediates, and finished products to detect and correct (FELLOWS et al., 2022). Moreover, information processing plays a major role in pharmaceutical production and quality control efforts. Advanced technology and data-driven approaches are used to successfully manage and analyze large datasets related to manufacturing processes, quality characteristics, and regulatory obligations. (WEITZEL et al., 2021) This comprises using computerized systems for data

gathering, processing, and reporting, as well as implementing quality management systems. The pharmaceutical industry involves enterprises engaged in the research and development (R&D), manufacturing, and distribution of medications (PAMMOLLI et al., 2011). Within this sector, pharmaceutical preparations undergo manufacturing, subjected to rigorous quality control protocols to ensure product safety and efficiency (GUADIX et al., 2019) Information processing technology is seamlessly integrated into various facets of the pharmaceutical industry, facilitating streamlined manufacturing operations, real-time monitoring of quality metrics (CRAIG et al., 2023), and compliance with regulatory restrictions (SAHA et al., 2023; ALGORRI et al., 2022)

Furthermore, healthcare providers depend on pharmaceutical items to provide effective treatment to patients, whether it's antiviral medications, antibiotics to treat secondary infections, or supportive therapy to control symptoms. Clinical practice itself has an impact on pharmaceutical supply chains by increasing demand for pharmaceuticals used to prevent, diagnose, and treat COVID-19 (ALI et al., 2020). In a pharmaceutical supply chain, humans depending on their role as patient and/or healthcare workers rely on access to medications to manage their symptoms and improve the outcomes and monitoring patient responses. As such, building supply chain resilience by managing supply chains by managers and manufacturers and addressing risk management played a significant role. As a result supply chain managers and manufacturers play an important role in enhancing supply chain resilience by successfully managing supply networks and resolving risk management issues (TAKAWIRA and POOE, 2024). This is due to supply chain managers and manufacturers play critical roles in orchestrating the flow of goods and materials, ensuring the timely production and distribution of pharmaceutical products (SARKIS et al., 2021)

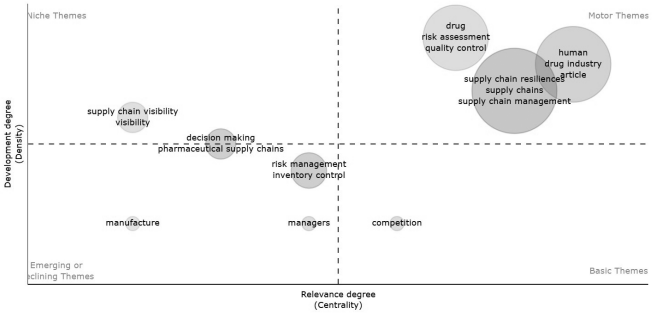
Another dimension of supply chain resilience within pharmaceutical supply chains is supply chain performance, which encompasses collaboration, coordination, and visibility. (BØ et al., 2023; NGUYEN et al., 2021) Additionally, supply chain visibility fosters collaboration and coordination among stakeholders by facilitating transparent real-time information sharing. This results in better decision-making and responsiveness to fluctuations coming from demand and / or supply, enhancing the inventory control (LÜCKER et al., 2019).

Figure 5. The Co-occurrence of Authors' keywords



Source: Authors' work

Figure 6: Thematic mapping



Source: authors' work.

Furthermore, pharmaceutical companies can gain quick visibility into their supply chain operations by using advanced technologies which enables implementation of data-driven solution with the aim of improving of performance and overall sustainable development (DEBNATH et al., 2023).

Figure 6 visualizes thematic mapping that represents the themes of a dataset organized in 4 clusters: motor themes, basic themes, niche themes, and emerging /declining themes.

Motor themes are broad notions or issues that are fundamental to pharmaceutical supply chain resilience with important concerns. They provide a high-level understanding of the major patterns driving the study. These driving areas include 'drug, risk assessment, quality control', 'supply chain resilience, supply chains, supply chain management', and 'human, drug industry, article'.

Basic themes assist researchers in identifying the variety of views leading to a more complete knowledge of the research. In basic themes, the primary focus is on'competition'. While competition can encourage innovation, cooperation, and market responsiveness in pharmaceutical sector (LIN and LEKHAWIPAT, 2023), it also creates obstacles and dangers to supply chain resilience (SHIRMOHAMMADI et al., 2023). Pharmaceutical businesses have to achieve a balance between competitive pressures and resilience demands. This can be done by implementing tactics that encourage innovation, cooperation, and agility while minimizing competition's effects on supply chain dependability (AHMAD et al., 2023). This can be achieved by implementing technology and innovation, developing strategic relationships with mid-term and long-term focus, and managing risks and decision-making (XU et al., 2023)

The Niche themes represent specialized topics not directly connected to supply chain resilience in pharmaceutical industry. The niche themes include 'supply chain visibility, visibility' and 'decision-making, pharmaceutical supply chains'. These topics are more focused on operational effectiveness to ensure chain resilience.

Additionally the declining theme is 'manufacture' this can be due to the researchers shifting their research interests in emerging 'risk management' and 'inventory control' and ' managers' related to logistics, suppliers, and information technology, neglecting the manufacturing-related issues in supply chain resilience research. Furthermore, as presented in the word of cloud, the researchers have emphasized their research in emerg-

ing new technologies and strategies such as additive manufacturing, robotics, and automation (STASEVYCH et al., 2023; JOSHI and PATEL, 2023). And the researchers are focused on digitization and agility, with new resilience strategies in order reshape manufacturing processes (SHETTY et al., 2023).

CONCLUSIONS

In recent years, research in the pharmaceutical supply chain has experienced significant growth, particularly post-COVID-19. This can be due to the COVID-19 revealing the significant gaps in addressing major disruptions and global dependency on pharmaceutical products. Scholars have delved into various dimensions of the pharmaceutical industry, focusing on areas like risk management, COVID-19 response strategies, inventory control, supply chain visibility, and technological advancements. This research trend marks a departure from the traditional emphasis on manufacturing, and now concentrating more on exploring effective ways to manage risks, optimize inventory control, and managerial practices within pharmaceutical supply chains.

Future research direction

1) What collaborative resilience strategies can pharmaceutical companies adopt to strengthen supply chain resilience?
2) What collaborative approaches can competitors in the pharmaceutical industry explore to address common challenges and drive collective innovation?
3) What are the implications of supply chain localization and regionalization for the resilience of pharmaceutical supply chains?
4) How can pharmaceutical supply chains integrate sustainability principles to enhance resilience?
5) How can pharmaceutical companies improve their risk management with the help of risk assessment frameworks, leveraging predictive analytics, modeling techniques, and integrating risk management into strategic decision-making processes?

Limitations:

This study analysis only the scholarly indexed by Scopus database, other databases can bring insights on the pharma supply chain resilience. Also, the time period studied is from 2012 until 2024.

Supplementary Materials:

For additional information please contact authors dienes.balasz@econ.unideb.hu and/or dejsi.qorri@econ.unideb.hu.

Author Contributions:

Methodology, D.Q.; software, D.Q.; validation, J.F., and B.B.D.; formal analysis, B.B.D.; data curation, D.Q.; writing-original draft preparation, B.B.D., J.F., & D.Q.; visualization, B.B.D.; supervision, J.F., project administration, J.F. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest:

The authors declare no conflicts of interest.

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