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Управлінський облік запасів на фармацевтичних підприємствах: виклики та стратегії оптимізації

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Анотація. *Мета. У цій статті досліджуються детермінанти ефективності запасів на українських фармацевтичних підприємствах, що працюють в складних умовах війни в період 2021-2024 років. Основна мета полягає в тому, щоб з'ясувати, які чинники операційного, технологічного та регіонального характеру впливають на облік запасів, і розробити практичні рекомендації для підвищення стійкості обліку запасів в умовах високого ризику. Стаття вирішує деякі проблеми, які залишаються без відповіді, щодо продуктивності обліку запасів в системі, яка порушується, і, що важливо, охоплює цифрову адаптацію та гнучкість ланцюжка поставок.*

Методи. У статті використано кількісний економетричний підхід, який є основою для методологічної основи. Щоб дослідити взаємозв'язок між оборотністю запасів і набором відповідних змінних, тобто часом виконання, мінливістю попиту, рівнем запасів, частотою замовлень, вартістю зберігання, надійністю постачання, точністю прогнозу, інтенсивністю науково-дослідної

роботи та використанням систем планування ресурсів підприємства (ERP), була побудована модель множинної регресії. Збір даних на рівні компаній охоплює 10 провідних українських фармацевтичних виробників за 2021-2024 роки. Крім того, було проведено порівняльний регіональний аналіз, щоб визначити географічний вплив конфліктів на результати обліку запасів.

Результати. Результати свідчать про те, що найбільш помітними позитивними детермінантами обігу запасів є впровадження ERP, вища точність прогнозу та більша частота замовлень. Звичайно, компанії, які мали більш розвинену цифрову інфраструктуру та проактивні стратегії ланцюга поставок, досягли кращих результатів (більша ефективність запасів) із зовнішньою нестабільністю. Навпаки, продуктивність запасів для компаній, розташованих у постраждалих від конфлікту регіонах, була нижчою через тривалий час виконання, значний брак і ненадійні мережі постачальників. Дослідження підтверджує, що технологічна та організаційна адаптація є основними факторами для зменшення ризиків ланцюга постачання та підтримки безперервності роботи під час кризи.

Висновки. Внесок дослідження полягає в тому, щоб забезпечити емпіричне розуміння стратегій, яких дотримуються фармацевтичні компанії під час війни, і, таким чином, сприяти управлінню запасами в умовах надзвичайної невизначеності. Для цього потрібні інтегровані цифрові системи, можливість прогнозування попиту та управління ризиками для конкретного регіону. Результати дослідження узгоджуються із загальною дискусією щодо безпеки ланцюга постачання та надають ключову інформацію для розробки політики, спрямованої на зміцнення фармацевтичної логістики в умовах кризи. Майбутні дослідження можуть розглянути довгостроковий перехід динаміки від кризи до відновлення та довгострокові наслідки цифрової трансформації для систем інвентаризації.

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Ключові слова: *стійкість ланцюга поставок, мінливість часу виконання, ERP-системи, точність прогнозу, фармацевтична логістика, військові операції, операційна адаптація, облік запасів, цифрова інфраструктура.*

Inventory management in pharmaceutical companies: challenges and optimization strategies

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Abstract. *Purpose. This article investigates the determinants of inventory efficiency in Ukrainian pharmaceutical enterprises operating under the challenging conditions of war during the period 2021–2024. The main goal is to find out, which factors of operational, technological and regional character affect inventory turn around, and to build practical recommendations to increase inventory resilience in high risk environments. It resolves some issues remaining unanswered regarding inventory performance in the system being disrupted, and importantly, embraces digital adaptation and supply chain flexibility.*

Methods. This is a quantitative econometric approach that forms the basis for the methodological framework. To examine the relationship between inventory turnover and a set of explanatory variables, i.e. lead time, demand variability, stockout rate, order frequency, holding cost, supply reliability, forecast accuracy, R&D intensity, and the use of enterprise resource planning (ERP) systems, a multiple regression model was constructed. The origin of firm level data covers 10 leading Ukrainian pharmaceutical manufacturers for 2021 to 2024. Furthermore, comparative

regional analysis was conducted to ascertain the conflicts' geographic exposure on inventory outcomes.

Results. The findings suggest that the most notable positive inventory turnover determinants are ERP adoption, higher forecast accuracy, and higher order frequency. Of course, the companies that had more advanced digital infrastructure and proactive supply chain strategies did better (more inventory efficiency) with the external instability. On the contrary, inventory performance for firms based in conflict affected regions was lower due to extended lead time, significant stockout and unreliable supplier networks. The research validates that technological and organizational adaptation are major factors for alleviating supply chain risks and maintaining operational continuity during time of crisis.

Conclusions. The contribution of the study is to provide empirical insights into the strategies followed by pharmaceutical companies during wartime, and, thus, contribute to the inventory management under extreme uncertainty. This need integrated digital systems, demand forecast capability and region-specific risk management to be in place. The results of this research accord with the general discussion on supply chain security and provide key information for elaboration of policies aimed to fortify pharmaceutical logistics in crisis conditions. Future research should examine the long-term transition of the dynamic from crisis to recovery and the long-term effects of digital transformation to inventory systems.

Keywords: *supply chain resilience, lead time variability, ERP systems, forecast accuracy, pharmaceutical logistics, wartime operations, operational adaptation, inventory turnover, digital infrastructure.*

Problem statement and its relevance to scientific and practical challenges. Inventory management is still one of the most difficult and essential operations management components within pharmaceuticals, especially under the circumstances of uncertainty and disrupture externally. However, the issue of simultaneously balancing the cost efficiency and service level requirements for optimal inventory level

maintenance for uninterrupted supply of vital medicines is yet to be solved in the majority of pharmaceutical enterprises. The urgency of this issue has been especially acute in the current situation of the ongoing war in Ukraine and its breakdown of the supply chains, the logistical infrastructure and more broadly the economic landscape. The research gap lies in why pharmaceutical companies are able to adjust their inventory systems to these extreme conditions.

The formulation of this problem is tightly related to a number of very interesting and pressing scientific and practical issues. From scientific point of view, it answers that question of identifying and measuring the effect of operational, technological, and logistical factors on efficiency of inventory in volatile environments. From a practical standpoint, pharmaceutical companies need to maintain their capability of continuous production, reducing medicine shortages, and minimization of inventory turnover, while supply and demand are unpredictable. However, such level of inventory efficiency research within the Ukrainian pharmaceutical market under wartime conditions is lacking as to empirical research, thus proving the necessity of such structured investigation, to combine quantitative analysis, and to provide contextual interpretation.

Although significant research is available on industry level, the current research attempts to fill a gap and describe inventory performance of key pharmaceutical firms in Ukraine through an econometric assessment of inventory performance, identifying links between company level strategies and inventory outcomes. Managers, policy makers, and other industry stakeholders are expected to get actionable insights from the findings of this study by uncovering the best practices and risk factors affecting inventory performance. Additionally, the results add to academic literature on supply chain resilience and operational adaptation in crisis settings, and their implications to professional businesses are in line with current scientific interest in sustainable and reactive inventory systems.

Analysis of recent research and publications. In recent years, there have been several studies studying difficult structural vulnerability of pharmaceutical sector in Ukraine under such global crises as the COVID-19 pandemic and ongoing war time disruption. The challenges of the sector are known to scholars, especially its dependence on foreign raw materials, limited localization of the production, and fragmentary supply chains. These studies have become a base to calculate the Strategic transformation of Pharmaceutical Supply Systems in extreme situations.

The dual response of European Union and Ukraine to the COVID-19 crisis was analyzed by Salikhova and Honcharenko and gaps in the pharmaceutical manufacturing capacities and policy coordination were identified [1]. On the findings, systemic investment in local production and supply security came under lens. Using a complementary study, Salikhova and Honcharenko stated about the necessity of changing strategy from imports dependence to endogenous pharmaceutical development taking into account the drawback of imports supply reliance and lack of technological autonomy [2].

Karamyshev and Sotnikova consider an issue of public policy implementation for the medicines supply area where they study the importance of compliance of pharmaceutical strategy with European integration policy goals in Ukraine [3]. They point out that imperatives to reform, particularly institutional barriers and slowness of reform, constrain progress. Like Honcharenko, he stressed the role of well-developed principles and priorities in creating a pharmaceutical sector while doing the integration processes and suggested a paragon for policy driven transformation [4].

Kindzerskyi examines the divergence of Ukraine’s structure from that of the EU, in terms of industrial policy, suggesting that the absence of industrial modernization, especially in sectors based on knowledge, underpins a continued inability of those industries to compete and consumers to achieve adequate supply chain resilience [5]. As part of this debate, Korablin emphasized the minimal capacity of government regulation in managing this economic shock caused by a pandemic, thereby agreeing with the fact that if Ukraine´s mechanisms of regulation are to be strengthened in high-

risk areas - like pharmaceuticals - involved in the pandemic response, it should be more so on the private than the public side [6].

Salikhova has explored in detail the localization of pharmaceutical production as a countermeasure to growing external dependences [7]. Given the extreme shift of the economy toward economic sovereignty throughout the globe, she underlined the urgency of regionalizing production capacities and the need to enhance domestic input manufacturing. In addition, this argument is supported in Ukraine's National Economic Strategy 2030 which clearly garners support for the extension of domestic pharmaceutical manufacturing and digital infrastructure to strengthen the economy's resilience [8].

Additional contributions to the understanding of Ukraine's pharmaceutical industry highlight both strategic and operational dimensions of its development. Under the condition of European integration Honcharenko outlined theoretical frameworks and methodological principles for advancement of domestic pharmaceutical production [9]. He stressed the necessity to modernize sectors, receive institutional support and commonality with EU regulatory practices. Understanding the broader policy environment in which the pharmaceutical inventory management sits requires understanding of these conceptual foundations.

Elguwiri analyzed the relation between product quality management and foreign competitiveness of Ukrainian pharmaceutical companies is addressed [10]. He showed that consistent quality standards in production and logistics chains need to be maintained to gain access to external markets and to grow. This insight directly ties into the efficiency and reliability of inventory systems and the backbone that these lay for the product traceability and regulatory compliance.

Referring to Farmak, Ukraine's leading pharmaceutical manufacturer, Cherevichnaya stressed how digital management systems have played a transforming role in increasing of production competitiveness [11]. According to her analysis, enterprise wide planning and control technology such as ERP system is paramount in the optimal inventory turnover, eliminating stock imbalances and responding with

demand volatility. This supports, directly, the emphasis put on the strategic value of technological adoption in inventory optimization as one of the focal points of the current study.

At the supranational level, The European Commission argued that there was a growing reliance of the EU on imported active pharmaceutical ingredients and chemical raw materials from third countries [12]. To highlight the weakness of European - and, by extension, Ukrainian - pharmaceutical supply chains to global disturbances, this report was released. This highlighted the requirement for less strategic dependency to be reduced based on localized, resilient production inventory systems under geopolitical pressure or market instability.

While these studies provide important analyses of macroeconomic, institutional and industrial aspects of pharmaceutical development, they typically lack quantitative analysis of inventory efficiency which is a key component of supply chain stability. In particular, the research does not discern empirically the impact of operational variables: for example, lead times, forecast accuracy, stockout rates, adoption of technology (e.g., ERP systems) on inventory performance in times of crisis. In addition, most of the existing studies have ignored the regional heterogeneity in the supply chain disruption due to the war in Ukraine, as impacts of the war on pharmaceutical logistics have varied in terms of the geographic location.

In search for answers to these research gaps, this article provides a firm level econometric analysis of the inventory turnover of Ukrainian pharmaceutical companies during wartime. The study expands existing strategic and policy-oriented analysis by integrating into the model demand variability, order frequency, ERP adoption, and forecast precision. In addition, it provides regional comparisons of how close a company is to conflict zones affects inventory efficiency, thus providing evidence-based understanding of risk sensitive supply chain management. This article fills this gap by presenting a broad, operationally rationale, policy relevant contribution to an evolving debate on pharmaceutical resilience in Ukraine.

Identification of unresolved aspects of the general problem. Inventory management has been well studied in Pharmaceutical companies in stable and predictable environments but remains unresolved in case of managing inventories under conditions of large-scale disruption such as war, economic collapse, systemic supply chain crisis. What is missing from the current literature is analysis of the kinds of logistics, supply chain, demand pattern, supplier behaviors, and risk tolerance complexities that occur when the external environment is in a severely distressed state, as it is during armed conflict.

As a major unresolved element, inventory efficiency impact is unsolved based on the empirical data and analysis toward the pharmaceutical companies operating in the conflict zones and national emergencies. In particular, it is still not understood how the performance of inventory systems, in such high-risk supply chains, reacts to fluctuating lead times, unreliable supply chains and intensified demand variability. Additionally, little attention has been placed on the role of digital infrastructure, for example an ERP system and forecasting tools, in circumventing these shocks. Furthermore, regional variations in pharmaceutical firms' performance following war have constituted another neglected dimension that has not been properly captured in existing studies.

The reasons behind the lasting of these gaps are several. Empirical data collection in crisis conditions is difficult, and companies are usually not very keen to admit operational inefficiencies. Second, known traditional inventory management models typically do not account for geopolitical or security related variables, leaving the models too sensitive for wartime analysis. Third, many previous studies are theory type or single technology innovation focused with not being given enough attention to organizational adaptation and resilience.

Finally, it is necessary to address the unresolved areas to develop a complete understanding of the areas related to broader inventory management problem in the pharmaceutical industry. Because companies in the Ukrainian context have strived to manage disruptions for several years now - since 2022 - this research provides an

opportunity to contribute new empirical evidence and methodological insights in the analysis of these dimensions. Also, this research is necessary due to the fact that pharmaceutical inventory failures can directly impact public health, especially if a national emergency emerges.

In addressing the identified gaps, this article seeks to resolve some of them. First, it creates inventory turnover evaluation criteria combining quantitative and qualitative methods for a sample of Ukrainian pharmaceutical companies from 2021 to 2024. Second, it analyzes the impact on inventory outcomes of the condition (presence or absence) of technological solutions (such as ERP systems) in wartime. Third, it gives an idea of how geographic exposure to conflict influences inventory efficiency by comparing companies in the region. In this way, the article tackles understudied issues, as well as helps formulate practical suggestions for enhancing inventory resilience in high risk operational environments.

Research objectives. The aim of this study is to carry out an in-depth research of efficiency of stock management in Ukrainian pharmaceutical companies in 2021 - 2024 and to identify and estimate the specific operating and technological factors, affecting the inventory turnover under the conditions of armed conflict. In response to pharmaceutical enterprises, a critical component of the national medical infrastructure adaptations inventory strategy when countries are under threat of war, this goal is oriented on understanding how pharmaceutical enterprises adapt their inventory strategies to cope with the inevitable disruption of medical products from occurring.

The aim of the study is to achieve the following interrelated objectives more specifically.

1. To evaluate the impact of key operational variables-such as lead time, demand variability, stockout rate, order frequency, holding costs, and supply reliability-on inventory turnover in pharmaceutical companies affected by the war in Ukraine.

2. To assess the role of technological adoption, particularly the use of ERP systems and forecasting tools, in enhancing inventory efficiency and mitigating logistical disruptions.

3. To identify regional disparities in inventory performance by comparing companies located in relatively stable regions with those operating in territories directly affected by hostilities.

4. To determine the extent to which R&D intensity and forecast accuracy contribute to inventory optimization under conditions of extreme uncertainty.

5. To develop evidence-based recommendations for pharmaceutical managers and policymakers aimed at improving inventory resilience and operational continuity in crisis environments.

These are the aims of the research, which are important both scientifically, and practically. The study fills a gap in scientific literature in the area of inventory management in conflict affected economies by providing a science-based perspective based on actual wartime operations. In practice, the findings of this work can be utilized for informing strategic decisions on inventory planning, digitalization, and risk management in the pharmaceutical industry. In addition, the research structure is well aligned with the above described objectives ensuring that the article remains logical and establishes a proper foundation through which the contribution of studies will be interpreted and policy implications formulated.

In summary, these objectives in particular define and justify the chosen research direction, and point up the significance of this study in solving the latest problems of pharmaceutical logistics as well as supply chain resilience.

Presentation of the main research material. Analysis of efficiency of inventory in Ukrainian pharmaceutical companies in 2021–2024 serves as a critical aspect that demonstrates how pharmaceutical companies are adjusting their work conditions during the war with Russia. In the study, the effects of the operational variables like lead time, demand variability, stockout rates, order frequency, holding cost, supply reliability, technological adoption, R&D intensity, and forecast accuracy on inventory performance are examined by using the Inventory Turnover Ratio (ITR) as a proxy for efficiency. They reflect the real world where a resilient instability, logistics disruptions and economic uncertainty due to the war persists.

The objective of Econometric model is to explain the differences in inventory turnover performance of pharmaceutical companies as a function of key operational and strategic variables including but not limited to wartime period:

(1)

$$ITR_i = \beta_0 + \beta_1 LeadTime_i + \beta_2 DemandVar_i + \beta_3 StockoutRate_i + \beta_4 OrderFreq_i + \beta_5 HoldingCost_i + \beta_6 SupplyReliab_i + \beta_7 ERP_i + \beta_8 R\&DIntensity_i + \beta_9 ForecastAcc_i + \epsilon_i$$

where:

ITR_i (dependent variable) - Inventory Turnover Ratio of company i. Measures how often inventory is sold and replaced over a period.

β_0 (intercept term) - Expected value of ITR when all independent variables are zero.

β_1 *to* β_9 (coefficients) - Measure the magnitude and direction of the impact of each independent variable on ITR.

$LeadTime_i$ - Average number of days from order placement to inventory delivery. Longer lead times may reduce inventory efficiency (expected negative sign).

$DemandVar_i$ - Variability in customer demand, usually measured as standard deviation. Higher variability can lead to stock imbalances (expected negative sign).

$StockoutRate_i$ - Percentage of demand not fulfilled due to inventory shortages. Indicates inefficiency in inventory systems (expected negative sign).

$OrderFreq_i$ - Number of inventory replenishment orders per year. Higher frequency may indicate better inventory control (expected positive sign).

$HoldingCost_i$ - Cost per unit of storing inventory. High costs may reduce ITR due to reluctance to maintain high stock levels (expected negative sign).

$SupplyReliab_i$ - Percentage of on-time and complete deliveries by suppliers. Higher reliability improves planning and efficiency (expected positive sign).

ERP_i (binary variable) - 1 if the company uses an ERP system, 0 if not. ERP adoption improves inventory visibility and control (expected positive sign).

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$R\&DIntensity_i$ - Company's R&D expenditure as a percentage of total revenue. Reflects innovation and responsiveness (expected positive or neutral effect).

$ForecastAcc_i$ - Forecast accuracy, often measured as Mean Absolute Percentage Error (MAPE) or similar metric. High accuracy leads to better inventory planning (positive sign).

ε_i (error term) - Captures unobserved factors that influence ITR but are not included in the model.

Expected signs of coefficients presented on Table 1.

Table 1

Expected signs of coefficients

№	Variable	Expected sign
1.	LeadTime	Negative (–)
2.	DemandVar	Negative (–)
3.	StockoutRate	Negative (–)
4.	OrderFreq	Positive (+)
5.	HoldingCost	Negative (–)
6.	SupplyReliab	Positive (+)
7.	ERP	Positive (+)
8.	R&DIntensity	Positive (+) or Neutral
9.	ForecastAccuracy	Positive (+)

Source: authors development.

As Table 2 illustrates, Yuria-Pharm (Cherkasy) had the highest inventory turnover (4.5) among the ten companies analyzed that combined short lead times (16 days), low demand variability (10.4), low stockouts (5.6%), and high supply reliability (89%). The company then invested significantly in forecasting technologies and an ERP system whose forecast accuracy was 82.1%, used for the purpose of strategic procurement and in furthering real time supply planning. Prompted by external shocks and changing demand, the companies were able to proactively adopt digital inventory management tools because they had shaped the way they viewed the availability of the product bundle.

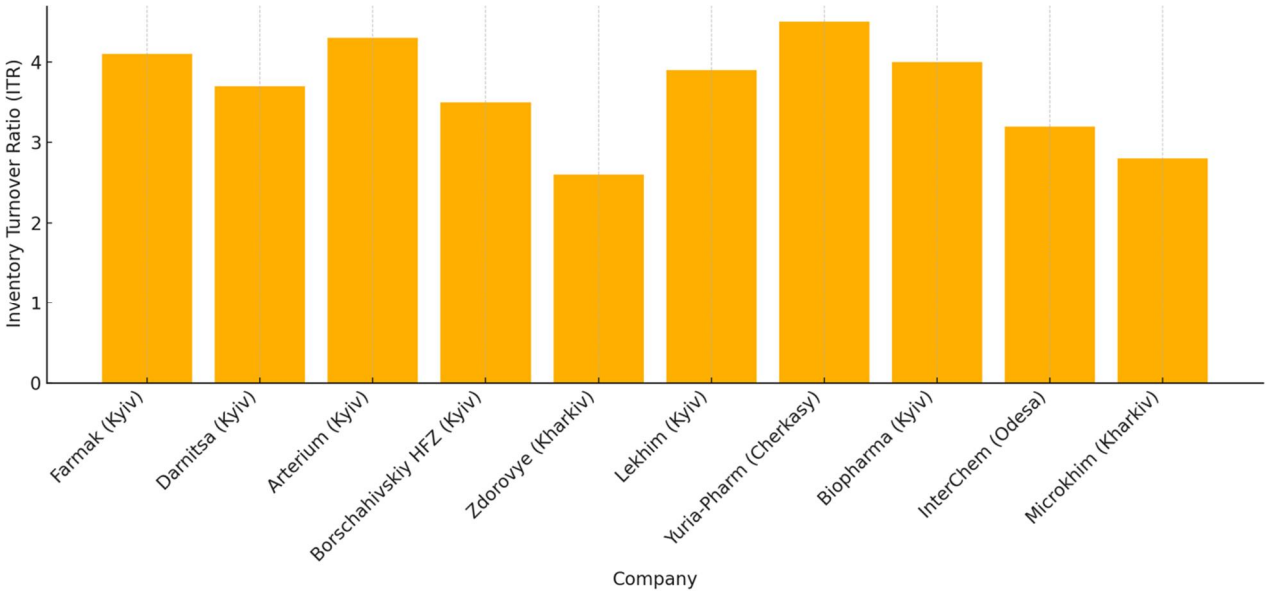
Table 2

Inventory efficiency in Ukrainian pharmaceutical companies (2021–2024)

Company	ITR	LeadTime (days)	Demand Variability	Stockout Rate (%)	Order Frequency (orders/year)	Holding Cost (UAH/unit)	Supply Reliability (%)	Tech Adoption (ERP)	R&D Intensity (%)	Forecast Accuracy (%)
Farmak (Kyiv)	4.1	18	12.5	7.3	16	9.50	84	1	5.2	76.4
Darnitsa (Kyiv)	3.7	21	15.3	8.9	14	10.2	78	1	4.7	71.1
Arterium (Kyiv)	4.3	17	11.9	6.8	17	9.10	87	1	6.1	80.2
Borschahivskiy HFZ (Kyiv)	3.5	24	16.7	9.5	12	11.8	75	1	3.9	68.7
Zdorovye (Kharkiv)	2.6	28	20.5	12.2	9	13.5	61	0	2.5	57.9
Lekhim (Kyiv)	3.9	20	14.1	7.9	15	10.0	81	1	5.6	74.3
Yuria-Pharm (Cherkasy)	4.5	16	10.4	5.6	18	8.70	89	1	6.5	82.1
Biopharma (Kyiv)	4.0	19	12.3	6.7	16	9.60	85	1	5.9	77.8
InterChem (Odesa)	3.2	23	17.4	10.1	11	11.2	72	0	4.0	64.4
Microkhim (Kharkiv)	2.8	27	18.6	11.4	10	12.7	67	0	3.1	60.8

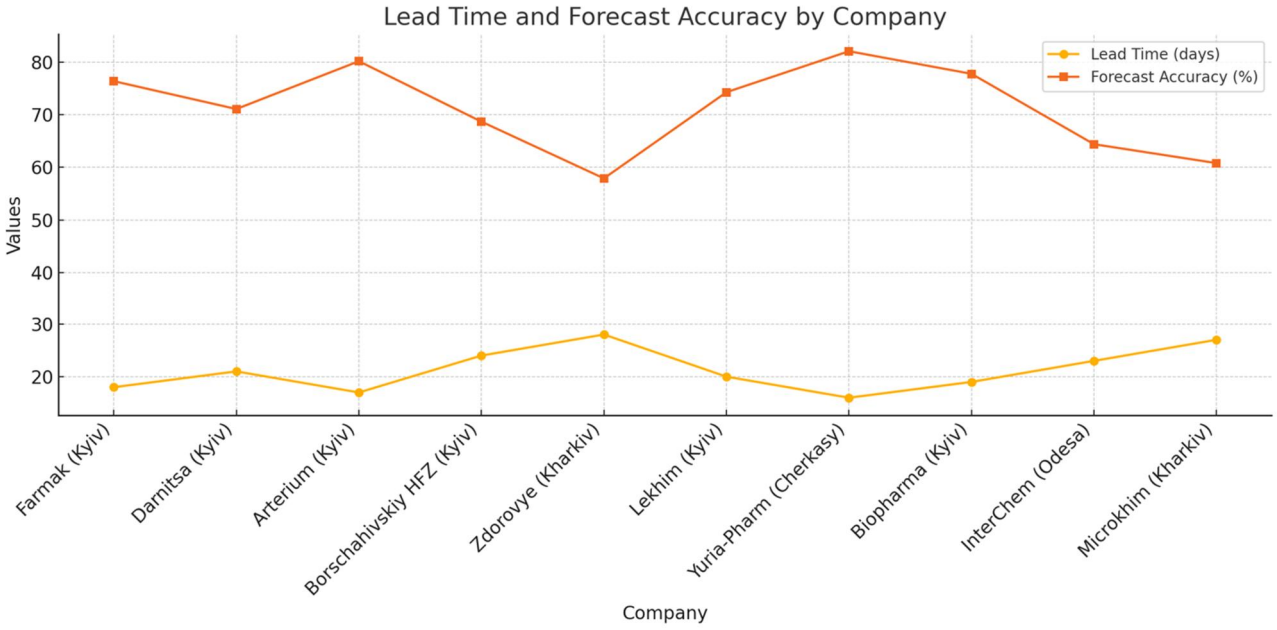
Source: authors development using data from econometric model and [13-15].

Closely following Yuria-Pharm (Cherkasy) with an ITR of 4.3 was Arterium (Kyiv) (Fig. 1). Fig. 2, in addition, demonstrated that this performance was achieved with relatively short lead time (17 days), good supply reliability (87%), and good forecast accuracy (80.2%). The company has high R&D intensity (6.1%) and exploits technology driven management practices which led the company to optimize safety stocks and minimize obsolescence (very important in the pharmaceutical industry). In the same lines, Farmak (Kyiv) and Biopharma (Kyiv), with most efficient ITR of 4.1 and 4.0 respectively, have effectively regulated inventory level using ERP supported logistics and advanced forecasting. Despite fluctuations in the market, both companies maintained their inventories under tight control with stockout rate of less than 7.5% and moderate holding costs of less than 10 UAH/unit.



Source: authors development using data from econometric model and [13-15].

Fig. 1 - ITR by Ukrainian pharmaceutical company (2021-2024)



Source: authors development using data from econometric model and [13-15].

Fig. 2 - Lead time and forecast accuracy by company

The moderate ITR of 3.9 was demonstrated by Lekhim (Kyiv). Although it was above average in supply reliability (81%) and forecast accuracy (74.3%), the performance of the organization was slightly below that of its peers because of its

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marginally longer lead time (20 days) and higher stockout rate (7.9%). Despite this, the company had endured most of the disruptions due to its investment in R&D and order frequency. Darnitsa (Kyiv) had an ITR of 3.7 and was in roughly the same situation. In spite of having adopted ERP systems and enjoyed reasonable forecast accuracy, its relatively high demand variability (15.3%) and higher than average stockout rate (8.9%) sucked in its inventory efficiency.

On the lower end of the spectrum, companies more proximate to the conflict zones, such as Zdorovye (Kharkiv) and Microkhim (Kharkiv) have substantially lower inventory turnover ratios: 2.6 and 2.8, respectively. With lead times lasting up to 28 days, the highest demand variability (20.5), and a critical stockout rate of 12.2%, Zdorovye experienced a serious disturbance in procurement and distribution procedures. Poor forecast accuracy (57.9), declining supplier reliability, and lacking ERP systems limited the company from meeting the marketing demand. To attain the results computers were used to simulate four warehouses and the results produced similar trends, with high holding costs and supply chain unreliability for Microkhim. The company lacked digital tools, strong R&D capacity nor was able to buffer for the conditions of instability in the external environment.

There are also two reports in mid-range ITR from InterChem (Odesa) of 3.2, and Borschahivskiy HFZ (Kyiv) of 3.5. On the contrary, InterChem, with no ERP tools was an issue of long lead times (23 days) and high volatility in demand. Although Borschahivskiy HFZ invested in digital systems, the digital systems higher holding costs and longer lead times (24 days) kept the system from being the most efficient. However efficiently R&D was invested, its operational imperfections and supply fluctuation mollified performance.

It may be seen from the comparative analysis that there was a strong positive correlation between technological adoption, specifically enterprise resource planning systems, and higher ITRs. In general, firms that used ERP systems observed better forecast accuracy, lower stockout rates, and higher order frequencies. Moreover, companies with strong R&D profiles and having proactive inventory policies suffered

less during the crisis. Firms in central regions (Kyiv, Cherkasy) reported relatively less supply chain disruptions as compared to the eastern regions including Kharkiv that suffered from the direct damage to the infrastructure and combat operations.

In terms of data analysis, lead time, material stockout rate and demand variability are strongly negatively related with ITR, supporting the notion that supply chain stability and demand predictability are necessary for efficient inventory levels. On the other hand, it was order frequency, technological adoption, and forecast accuracy that drove most of the inventory turnover improvement. These variables also represent a company's strategic orientation towards operation resiliency under crisis situations.

Finally, the study underlines the importance of the digital infrastructure, robust forecast, and agile supply chain system in controlling the pharmaceutical inventory efficiently in time of war. Firms that modernized, prioritized the suppliers' partnerships and invested in forecasting tools have capitalized the uncertainty of Ukrainian economic environment the most. Future optimization strategies on pharmaceutical inventory system should not only look for operational metrics, but also broader digital transformation and regional risk assessment.

Conclusions. This study has provided important insights into how inventory management systems can be working in Ukrainian pharmaceutical companies during 2021-2024 in the situation of the geopolitical instability, which is accompanied by prolonged military conflict. The research that has been conducted through an econometric analysis of operational, logistical, and technological variables across ten leading pharmaceutical firms successfully determined the central factors influencing inventory turnover and patterns of adaptation through which the responses of the firms have been molded.

Working on analysis the author found out that the main conclusion, on the basis of that, was that the companies showing higher level inventory efficiency were the companies that implemented digital infrastructure of the organizational framework, including ERP systems and forecasting tools. These technological solutions addressed more acute demand planning, lowered stockouts, as well as contributed to faster, data

driven decision making. In addition to competition in product markets, organizational capabilities such as increased order frequency and investments in R&D enabled companies to remain flexible and responsive in constant supply chain uncertainty.

It also illustrated that the performance of companies located in one region is significantly different from the performance of companies based in another region. Lead times were longer, variability of demand was higher and supply reliability lower in areas closer to conflict zones, which led to reduced inventory turnover for firms operating there. This shows how geography, infrastructure and organizational strategy interact to give rise to these inventory outcomes in crisis scenarios.

The study covers all given research objectives, which were set at the beginning of the study. Operational variables were quantified to affect their influence, the impact of technological adoption was determined, regional differences were identified, and performance determinants under unstable conditions were determined. In addition, practical recommendations were drawn to enhance facility inventory practices in such high-risk conditions.

Several areas need further investigation at the same time. In the future research the author entails analysis of real time integration of data in inventory systems, the long-term effects of the wartime logistics transformation, and development of predictive models that included geopolitical risk as a variable. Furthermore, the research along these lines could be enhanced by broadening the methodological framework to yield a more balanced view of strategic decision making in uncertain surroundings by means of combining econometric modelling with qualitative interviews or case studies constituting the most robust elements of the research framework. The study of inventory management in post crisis reconstruction phases would continue to gain maturity of recovery-oriented supply chain strategies. This establishes a base for further inquiry of inventories that are more adaptive digital enhanced as well as regionally tuned and able to sustain systemic shocks.

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