World Economy and International Economic Relations

UDC 339.564:004.8:519.23:658.8

DOI https://doi.org/10.5281/zenodo.18622144

Prediction of export sales volumes using machine learning in conditions of unstable demand

Ivan Pankulych,

Master's Degree in Management, Founder & Executive Director,

American Institute for Global Trade, Management & Economic Diplomacy,

Sacramento, USA, https://orcid.org/0009-0002-7901-1257

Accepted: 27.01.2026 | Published: 12.02.2026

Abstract. *The relevance of the study stems from the increasing instability of demand in foreign markets, the volatility of macroeconomic and market factors, the disruption of logistics chains, and the growing uncertainty surrounding conditions for implementing export activities. In such a situation, traditional approaches to forecasting export sales volumes do not provide sufficient accuracy and adaptability, which makes the application of machine learning methods relevant, as they can account for the multifactoriality and nonlinearity of market processes. The* ***purpose of the article*** *is to scientifically substantiate and develop approaches to forecasting export sales volumes based on machine learning methods in conditions of unstable demand in order to increase the accuracy of forecast estimates and the quality of management decisions in the field of export activities.* ***Methods****. The study uses systemic and analytical approaches, methods of theoretical generalization, structural-logical analysis and comparison to systematize modern approaches to forecasting economic indicators. A conceptual analysis of forecasting models is*

used, taking into account multifactoriality, nonlinearity and instability of time series. ***Results****. The impact of macroeconomic, market, political, regulatory, and logistical factors on demand instability and the dynamics of export sales is analyzed. Methodological approaches to the application of regression, ensemble, and neural network machine learning models for forecasting in the presence of nonlinearity and structural changes are summarized. Problems with the practical use of such models are identified, including data instability, structural breaks in time series, and limited interpretability of results.* ***Conclusions****. The feasibility of using machine learning methods for forecasting export sales volumes under unstable demand is confirmed as a tool for improving the analytical quality of forecasts and the effectiveness of management decisions. The need to integrate such models into the export management support system of enterprises is substantiated. Prospects for further research include the development of interpreted and hybrid forecasting models, the improvement of methods for analyzing unstable time series, and the formalization of procedures for automatic detection of structural breaks in the dynamics of export sales.*

Keywords: *foreign economic activity, sales forecasting, market volatility, time series analysis, adaptive models, managerial decision-making, data analytics.*

Прогнозування обсягів експортних продажів із застосуванням машинного навчання в умовах нестабільного попиту

Панькулич Іван,

магістр (менеджмент), засновник та виконавчий директор,

American Institute for Global Trade, Management & Economic Diplomacy,

м. Сакраменто, США, https://orcid.org/0009-0002-7901-1257

Анотація. *Актуальність дослідження зумовлена зростанням нестабільності попиту на зовнішніх ринках, підвищенням волатильності*

макроекономічних і ринкових чинників, порушенням логістичних ланцюгів та зростанням невизначеності умов здійснення експортної діяльності. У такій ситуації традиційні підходи до прогнозування обсягів експортних продажів не забезпечують достатньої точності та адаптивності, що актуалізує застосування методів машинного навчання, здатних ураховувати багатофакторність і нелінійність ринкових процесів. ***Мета статті*** *полягає у науковому обґрунтуванні та розробленні підходів до прогнозування обсягів експортних продажів на основі методів машинного навчання в умовах нестабільного попиту з метою підвищення точності прогнозних оцінок та якості управлінських рішень у сфері експортної діяльності.* ***Методи****. У дослідженні застосовано системний і аналітичний підходи, методи теоретичного узагальнення, структурно-логічного аналізу та порівняння для систематизації сучасних підходів до прогнозування економічних показників. Використано концептуальний аналіз моделей прогнозування з урахуванням багатофакторності, нелінійності та нестабільності часових рядів.* ***Результати****. Проаналізовано вплив макроекономічних, ринкових, політико-регуляторних та логістичних чинників на нестабільність попиту й динаміку експортних продажів. Узагальнено методологічні підходи до застосування регресійних, ансамблевих та нейромережевих моделей машинного навчання для прогнозування в умовах нелінійності та структурних змін. Виявлено проблеми практичного використання таких моделей, пов'язані з нестабільністю даних, наявністю структурних зламів часових рядів і обмеженою інтерпретованістю результатів.* ***Висновки****. Підтверджено доцільність використання методів машинного навчання для прогнозування обсягів експортних продажів в умовах нестабільного попиту як інструменту підвищення аналітичної якості прогнозів та результативності управлінських рішень. Обґрунтовано потребу інтеграції таких моделей у систему підтримки управління експортною діяльністю підприємств. Перспективи*

подальших досліджень пов'язані з розробленням інтерпретованих і гібридних моделей прогнозування, удосконаленням методів аналізу нестабільних часових рядів та формалізацією процедур автоматичного виявлення структурних зламів у динаміці експортних продажів.

Ключові слова: *зовнішньоекономічна діяльність, прогнозування продажів, нестабільність ринку, часові ряди, адаптивні моделі, управлінські рішення, аналітика даних.*

Problem statement. Modern processes of international trade development are characterized by increasing volatility in demand in foreign markets, driven by macroeconomic instability, geopolitical risks, disruptions in global supply chains, currency fluctuations, and rapid changes in consumer preferences. Under such conditions, traditional approaches to forecasting export sales volumes, based on linear trends, expert assessments, or deterministic econometric models, prove insufficiently accurate and poorly suited to nonlinear market dynamics. This complicates the adoption of sound management decisions in production planning, logistics, contract formation, and financial forecasting, which directly affects the competitiveness of enterprises in international markets.

In this regard, the scientific problem of developing methods for forecasting export sales volumes that can effectively account for demand instability, structural breaks in time series, the influence of a multifactor environment, and hidden relationships among economic, market, and operational indicators is becoming increasingly relevant. The application of machine learning methods opens new opportunities for solving this problem by enabling algorithms to automatically detect complex nonlinear patterns, adapt to changing market conditions, and process large arrays of heterogeneous data, including historical sales volumes, macroeconomic indicators, seasonal factors, and information about the market situation.

The practical significance of this problem lies in the development of scientifically based approaches to improve the accuracy of export sales forecasts, reduce the risk of excess or deficit production, optimize export logistics, and enhance enterprises' resilience to external shocks.

At the same time, in the scientific dimension, the study of this issue is associated with solving important tasks of developing applied methods for analyzing unstable time series, integrating the economic content of indicators into machine learning models, and adapting forecasting algorithms to conditions of high uncertainty, which is of significant importance for the further development of economic and mathematical modeling in the field of foreign economic activity.

Analysis of recent research and publications. A review of modern research indicates a gradual complication of methodological tools and an expansion of the factor field of forecasting models. In scientific works, the transition from the use of individual algorithms to complex analytical approaches that take into account the nonlinear dynamics of foreign markets and the high level of uncertainty is increasingly evident. In the first group of studies, the emphasis is on applying classical and neural network machine learning methods for direct forecasting of export volumes. The work of V. Sohrabpour et al. substantiates the feasibility of using artificial intelligence algorithms to forecast export sales, demonstrating their superiority over traditional econometric models under unstable demand conditions [1]. P. Suler et al. evaluated the accuracy of machine forecasting of the Czech Republic's exports to China, confirming the high adaptability of the models to changes in foreign trade conditions [2]. C. Dai proposed a method for forecasting export volumes using a neural network with backpropagation of errors, which increases forecast accuracy in the medium term [3].

The next body of research focuses on accounting for macroeconomic and exogenous factors in machine-based export forecasting. H. Zhu conducted an AI-oriented analysis of oil demand forecasting in exporting and importing countries,

demonstrating the importance of comprehensively considering endogenous and exogenous factors [4]. H. Jia et al. applied machine learning methods to forecast global oil export directions, focusing on the impact of structural changes in world markets on export flows [5]. T. Akhter et al. combined a nonlinear autoregressive model with machine learning algorithms to forecast Bangladeshi exports, identifying key factors constraining export dynamics in the face of external shocks [6].

A separate group consists of studies that use machine learning to forecast export sales, taking into account logistical, market, and natural and climatic factors. J. K. Pelekamoyo and H. M. Libati have demonstrated the effectiveness of machine learning for forecasting supply and demand, accounting for local weather conditions [7]. M. C. Camur et al. have proposed an approach to forecasting product availability in supply chains under disruption conditions, which is of direct importance for planning export sales [8]. M. Muth et al., in a systematic review of the literature have summarized approaches to forecasting demand under macroeconomic volatility, emphasizing the growing role of adaptive machine learning models [9].

Of considerable interest are interdisciplinary studies that consider export sales forecasting alongside behavioral, marketing, and institutional factors. D. Kyiashko has proposed a hybrid framework for testing multimodal systems based on AI agents, which forms methodological prerequisites for increasing the reliability of forecast models [10]. V. Ganchev investigated the use of artificial intelligence technologies in automotive marketing, focusing on personalization as a factor in stabilizing demand [11]. V. Levit analyzed the impact of ESG strategies on the brand of a territory, which indirectly affects the long-term sustainability of export demand [12]. Y. Hrushko examined the cultural adaptation of brand messages of Ukrainian companies in the fast-moving consumer goods sector when entering the European Union markets as a factor in shaping the context for forecasting export sales [13]. M. Bogopolskyy and N. Cherep investigated aesthetic and neuromarketing markers

of consumer trust, which are increasingly integrated into data-driven demand models [14; 15].

Identification of previously unresolved parts of the general problem. Despite significant research on forecasting foreign economic indicators, the issues of carefully accounting for demand instability, structural breaks in time series, and the multifactorial nature of export sales remain unresolved. Existing machine learning approaches are mainly focused on improving forecast accuracy but lack interpretability and are not well suited to abrupt changes in the market environment, hindering their practical use in export management.

The proposed research aims to overcome these gaps by combining the analysis of demand instability factors with the generalization and development of machine learning approaches that account for the nonlinearity and dynamism of export processes. The work justifies the use of such models as tools for supporting management decisions, thereby increasing the practical applicability of forecasts and expanding the scientific understanding of forecasting export sales under unstable demand conditions.

Formulation of the article's goals (task statement). The purpose of the article is to develop and scientifically substantiate approaches to forecasting export sales volumes using machine learning methods in conditions of unstable demand in order to increase the accuracy of forecasting and the effectiveness of management decisions in the field of export activities.

To achieve the goal, the article sets the following tasks:

1. To analyze the nature of the instability of demand in export markets and summarize the factors that determine the dynamics of export sales volumes in a changing market environment.

2. To summarize and systematize modern methodological approaches to the application of machine learning methods to forecast economic indicators of foreign

economic activity, taking into account the multifactorial nature and nonlinearity of market processes.

3. To substantiate the possibilities and limitations of using machine learning models in forecasting export sales and to develop practical recommendations for their integration into the system for managing the export activities of enterprises in conditions of unstable demand.

Presentation of the main material of the study. In the context of modern international trade, demand instability in export markets is driven by interrelated economic, political, and market factors, leading to increased volatility in export sales volumes. Fluctuations in macroeconomic indicators, changes in trade regulations, logistical restrictions and transformation of consumer preferences lead to uneven export dynamics, the appearance of structural breaks in time series and an increase in the gap between forecast and actual sales values, which significantly complicates the processes of planning and managing export activities of enterprises (table 1).

Table 1

Main factors of demand instability in export markets and their impact on export sales

Group of factors	Content characteristics	Nature of impact on export sales dynamics
Macroeconomic	Fluctuations in GDP, inflation, exchange rates, and consumer solvency	Uneven changes in sales volumes, increased volatility of demand
Political and regulatory	Trade restrictions, sanctions, changes in customs tariffs, export quotas	Dramatic reductions or temporary suspensions of export supplies
Logistics	Supply chain disruptions, increased transportation costs, and infrastructure deficit	Shifting delivery times, instability of actual export volumes
Market	Increasing competition, changes in consumer preferences, and the emergence of substitute goods	Short-term fluctuations and structural changes in demand
Financial	Limited access to financing, growth, and cost of credit resources	Reduction in order volumes and increased risk of contract rejection

Source: based on [1; 4; 6; 9, p. 2763; 13, p. 35; 16; 17, p. 100]

The practical implications of the factors listed in the table are manifested in specific, measurable effects that directly transform the dynamics of enterprises' export sales in the current conditions of unstable demand. Thus, according to the World Bank, during periods of sharp currency fluctuations, the average deviation of actual export volumes from forecast values in countries with open economies increases by 18–25%, with the most sensitive sectors being those with long contract cycles and a high share of import components in the cost of production [18]. In practice, this means that even with stable physical demand, currency shocks can lead to the revision of export contracts, the postponement of deliveries, or the reduction of goods batches, resulting in an uneven and fragmented trajectory of export sales over time.

Another illustrative example is the impact of logistical factors, in particular the increase in the cost of sea transportation and disruption of global supply chains. According to UNCTAD estimates, an increase in the container transportation cost index by 3–4 times compared to the pre-crisis level led to a decrease in the physical volumes of exports of individual commodity groups by 20–30% and an extension of the terms of execution of export contracts by an average of 20–35 days [19]. In practical terms, this translates into shifts in the timing of income realization, increased finished-product inventory, and increased financial risks, which significantly complicate short- and medium-term forecasting of export sales based on historical data [6]. These examples indicate that demand instability in export markets is not abstract but clearly measurable, manifested through specific numerical parameters of volatility, time shifts, and structural changes in sales. In current conditions, these effects enhance the nonlinearity of export indicator dynamics and reduce the effectiveness of traditional forecasting models that assume relative stability in the external environment. That is why analyzing demand instability factors based on real empirical examples provides a scientifically sound basis for the further application of adaptive forecasting methods that can account for

rapid changes in market conditions and enhance the practical value of export sales forecasts.

In modern studies of foreign economic activity, machine learning methods are considered tools for building adaptive forecasting models that can operate under conditions of high uncertainty, incomplete information, and rapid changes in market parameters. The methodological evolution of forecasting economic indicators of exports is associated with the transition from parametric models to algorithms based on learning from data, which allow for the consideration of complex nonlinear dependencies, the multidimensionality of the factor space, and the temporal variability of influences. In this context, machine learning is used not only to improve forecast accuracy, but also to identify hidden patterns in the dynamics of foreign economic indicators that have practical value for managing export activities (table 2).

Table 2

Application of machine learning methods in forecasting economic indicators of foreign economic activity

Methodological approach	Basic idea of modeling	Typical economic indicators
Machine learning regression models	Construction of nonlinear dependencies between the target indicator and a set of factors	Export volumes, export revenue, contract prices
Ensemble methods	Combining the results of several models to reduce forecast error	Sales volumes by markets, product groups
Deep learning methods	Modeling complex temporal and spatial dependencies in large data sets	Export dynamics, seasonal and cyclical fluctuations
Hybrid approaches	A combination of econometric models and machine learning	Forecasting taking into account economic interpretation
Online and adaptive learning	Continuous updating of the model as new data arrives	Short-term forecasts of export indicators

Source: based on [1; 2; 3, p. 8778; 9, p. 2766; 10, p. 1779]

The integration of machine learning methods into the forecasting of economic indicators of foreign economic activity consists of building models that are directly embedded in export planning, contract management, and financial forecasting.

Regression and ensemble algorithms are widely used to forecast export volumes by country and commodity. When based on historical sales data, exchange rates, and price indicators, these methods achieve a reduction in the average absolute error of the forecast by 12–18% compared to linear econometric models. This result is confirmed by the experience of analytical departments in export-oriented industrial and agricultural companies [3, p. 8778]. Deep learning methods are applied when export indicators show complex temporal structures, unstable seasonality, and repetitive but non-hierarchical patterns. In international trading companies, the use of recurrent neural networks enables more accurate short-term demand forecasting and reduces monthly export volume forecast error by 15–25% [20]. This accuracy is critically important for operational production and logistics management [9, p. 2766]. Hybrid approaches combine econometric models with machine learning algorithms. They maintain economic interpretability while enabling high adaptability. In practice, this allows for scenario forecasts of export indicators and clearly distinguishes among the influences of price, currency, and volume factors, thereby increasing the value of the results for management. Adaptive and online models are used when data updates are frequent. Regular review of forecasts, weekly or even daily, reduces risks like unsold stock accumulation or disruption of export supplies. Altogether, these approaches ensure the practical applicability of machine learning in forecasting foreign economic indicators. They focus not only on model accuracy but also on real-world managerial usefulness for export-oriented enterprises.

Multifactoriality and nonlinearity of market processes fundamentally change the requirements for forecasting export sales volumes. Export outcomes depend not on isolated variables, but on their interactions, time lags, and contextual effects. In modern conditions, export sales are shaped by several factors. These include price parameters, currency fluctuations, contract terms, production constraints, sales-market characteristics, and behavioral responses of counterparties. These factors

change unevenly and asynchronously. Such complexity makes it impossible to adequately describe sales dynamics using linear or low-parameter models. This drives the use of machine learning methods that can model complex nonlinear dependencies in high-dimensional feature spaces (table 3).

Table 3

Machine learning models for forecasting export sales volumes, taking into account multifactoriality and nonlinearity

Model type	Features of taking multifactoriality into account	Character of work with nonlinear dependencies
Decision trees and ensembles	Automatically selects significant factors and their combinations	Modeling of threshold and asymmetric effects
Neural networks	Simultaneous processing of a large number of interrelated variables	Identification of complex nonlinear functional dependencies
Temporal neural models	Taking lags and dynamic relationships of factors into account	Adapting to changes in the structure of time series
Factor-oriented models	Integration of aggregated economic and market indicators	Generalization of nonlinear effects at the level of latent factors
Combined multilevel models	A combination of different types of features and models	Stabilization of forecasts under conditions of complex market dynamics

Source: based on [2; 3, p. 8781; 5, p. 119; 8; 9, p. 2771; 21; 22]

Building machine learning models for forecasting export sales volumes in a multifactor, nonlinear market environment is, in practice, based on constructing a feature space in which indicators are treated as interconnected elements of a single system. The model learns not to reproduce an averaged trend but to identify stable configurations of factors that precede changes in export sales dynamics across different market conditions. In applied export analytics systems, this allows us to correctly describe situations in which the same values of individual parameters yield different results depending on the context. For example, changes in contract terms affect export volumes differently across sales markets, delivery times, and prior sales dynamics, which is reflected in the model through nonlinear feature interactions without a prior specification of a functional form [9, p. 2771]. An important advantage of such models is their ability to account for time lags and cumulative

effects when the impact of management or market decisions manifests with a delay. The application of sequential data representations enables us to separate short-term fluctuations from structural shifts in export sales dynamics, thereby improving the stability of medium-term forecasts. The scientific and practical significance of machine learning models lies in the ability to integrate heterogeneous economic and market indicators into a single forecasting system without losing sensitivity to the specifics of individual markets and products [21]. In modern conditions, such models serve as an analytical basis for scenario planning of export activities and for assessing the consequences of management decisions in complex, nonlinear market dynamics.

The use of machine learning methods for forecasting export sales is accompanied by several scientific and practical problems that limit the stability and reliability of forecast results in the real operating conditions of foreign economic systems. One of the key problems is the instability of the initial data, due to irregular export operations, changes in contract terms, incomplete statistical information, and the asynchrony of data receipt from different sources. This violates the assumptions of time-series stationarity, on which the training of most models is based, and reduces the ability of algorithms to correctly generalize past experience to new periods [23; 24]. A significant complication is the presence of structural breaks in the dynamics of export sales, associated with sharp changes in market conditions, the regulatory environment, or logistics. In such situations, a model trained on previous data begins to reproduce outdated patterns, leading to systematic forecast errors and requiring frequent retraining or architectural restructuring [4]. At the same time, the lack of clear criteria for automatically detecting moments of structural breaks complicates the integration of these processes into practical forecasting systems. A separate scientific and practical problem is the limited interpretability of machine learning model results, especially when complex ensemble or neural architectures are used. The inability to clearly explain which factors and their

combinations determine the forecast reduces management personnel's confidence in the results and complicates the use of models in the strategic planning of export activities [13, p. 36]. Additional difficulties arise when transferring models across markets or product groups, since local features of demand and contractual relationships are often not reflected in the structure of the training samples.

The practical implementation of machine learning models into the export management systems of enterprises in conditions of unstable demand is advisable to be carried out by integrating them into the management decision support system, rather than as an autonomous forecasting tool. This provides a combination of model estimates, scenario analysis, and expert interpretation, reducing the risk of erroneous decisions in an environment of high uncertainty. An important condition for the effective use of models is regular updating and monitoring of their predictive suitability, taking into account changes in market conditions and structural breaks in the dynamics of export sales. Practice shows the feasibility of using multiple models across different time horizons, enabling coordination of operational and strategic decisions in export activities. To enhance the managerial value of forecasts, it is advisable to ensure the interpretability of model results by analyzing the impact of key factors on forecast estimates. This makes it possible to use machine learning not only to predict export sales volumes, but also to substantiate decisions on pricing policy, selection of sales markets and contract parameters. In practical terms, the effectiveness of implementing machine learning models increases when they are integrated with production planning, logistics, and financial management systems, enabling the prompt translation of forecast results into specific management actions. The implementation of such recommendations lays the groundwork for increasing the sustainability of enterprises' export activities in conditions of unstable demand.

Conclusions. The study found that forecasting export sales volumes under unstable demand requires the use of adaptive models that can account for the multifactorial, nonlinear nature of market processes and structural breaks in time

series. It is proven that machine learning methods provide a scientifically sound basis for improving the analytical quality of forecasts and supporting management decisions in export activities.

It was found that the key scientific and practical problems in applying machine learning are instability and heterogeneity of data, the loss of predictive relevance of models in the face of sharp changes in market conditions, and limited interpretability of results, which complicates their use in strategic management. It has been established that without regular model updates and their integration into management processes, the risk of reproducing outdated patterns increases. The feasibility of implementing machine learning models as elements of a management decision support system, while ensuring the interpretability of forecasts, supporting scenario analysis, and coordinating with the enterprise's production, logistics, and financial processes, is substantiated.

Prospects for further research include the development of algorithms resistant to data instability, methods for automatic detection of structural breaks, and the creation of interpretable hybrid models for forecasting export sales in an environment of high market uncertainty.

References

1. Sohrabpour V., Oghazi P., Toorajipour R., Nazarpour A. Export sales forecasting using artificial intelligence. *Technological Forecasting and Social Change*. 2021. Vol. 163. Article 120480. DOI: https://doi.org/10.1016/j.techfore.2020.120480.

2. Suler P., Rowland Z., Krulicky T. Evaluation of the accuracy of machine learning predictions of the Czech Republic's exports to China. *Journal of Risk and Financial Management*. 2021. Vol. 14, № 2. Article 76. DOI: https://doi.org/10.3390/jrfm14020076.

3. Dai C. A method of forecasting trade export volume based on back-propagation neural network. *Neural Computing and Applications*. 2023. Vol. 35, № 12. P. 8775–8784. DOI: https://doi.org/10.1007/s00521-022-07693-5.

4. Zhu H. Oil demand forecasting in importing and exporting countries: AI-based analysis of endogenous and exogenous factors. *Sustainability*. 2023. Vol. 15, № 18. Article 13592. DOI: https://doi.org/10.3390/su151813592.

5. Jia H., Adland R., Wang Y. Global oil export destination prediction: a machine learning approach. *The Energy Journal*. 2021. Vol. 42, № 4. P. 111–130. DOI: https://doi.org/10.5547/01956574.42.4.hjia.

6. Akhter T., Ratna T. S., Ahmed F., Babu M. A., Hossain S. F. A. Forecasting and unveiling the impeded factors of total export of Bangladesh using nonlinear autoregressive distributed lag and machine learning algorithms. *Heliyon*. 2024. Vol. 10, № 17. Article e36274. DOI: https://doi.org/10.1016/j.heliyon.2024.e36274.

7. Pelekamoyo J. K., Libati H. M. Forecasting market's demand and supply with machine learning and local weather. *International Journal of Scientific and Technology Research*. 2022. Vol. 11, № 1. P. 115–119. URL: https://www.researchgate.net/profile/Jephter_Pelekamoyo/publication/358462306_Forecasting_Markets_Demand_And_Supply_With_Machine_Learning_And_Local_Weather/links/6203a63782638c2de5212fc0/Forecasting-Markets-Demand-And-Supply-With-Machine-Learning-And-Local-Weather.pdf (access date: 20.11.2025).

8. Camur M. C., Ravi S. K., Saleh S. Enhancing supply chain resilience: a machine learning approach for predicting product availability dates under disruption. *Expert Systems with Applications*. 2024. Vol. 247. Article 123226. DOI: https://doi.org/10.1016/j.eswa.2024.123226.

9. Muth M., Lingenfelder M., Nufer G. The application of machine learning for demand prediction under macroeconomic volatility: a systematic literature

review. *Management Review Quarterly*. 2025. Vol. 75, № 3. P. 2759–2802. DOI: https://doi.org/10.1007/s11301-024-00447-8.

10. Kyiashko D. Development of a hybrid testing framework for multimodal systems based on AI agents. *Наука і техніка сьогодні*. 2025. № 11(52). С. 1774–1788. DOI: https://doi.org/10.52058/2786-6025-2025-11(52)-1774-1788.

11. Ganchev V. Automotive business marketing with the use of artificial intelligence technologies for service personalization. *Актуальні питання економічних наук*. 2025. № 15. DOI: https://doi.org/10.5281/zenodo.17060084.

12. Levit V. ESG strategies in the event industry and their impact on the brand value of a territory. *Здобутки економіки: перспективи та інновації*. 2025. № 24. DOI: https://doi.org/10.5281/zenodo.17669205.

13. Грушко Є. Культурна адаптація меседжів бренду при виході українських FMCG-компаній на ринки ЄС. *Актуальні питання економічних наук*. 2025. № 15. DOI: https://doi.org/10.5281/zenodo.17862461.

14. Bogopolskyy M. Aesthetic economy as a driver of commercial space choice among generation Z. *Здобутки економіки: перспективи та інновації*. 2025. № 25. DOI: https://doi.org/10.5281/zenodo.17953680.

15. Cherep N. Neuromarketing trust markers in luxury brand communications. *Scientific Notes of Lviv University of Business and Law*. 2025. № 46. P. 527–535. DOI: https://doi.org/10.5281/zenodo.17846691.

16. Hasenko Y. Enhancing the environmental safety of logistics processes through optimal supply planning. *Здобутки економіки: перспективи та інновації*. 2025. № 20. DOI: https://doi.org/10.5281/zenodo.17898105.

17. Гетманенко О. О. Економіка війни: вплив сучасних військових конфліктів на глобальну економічну стабільність. *Актуальні проблеми економіки*. 2025. № 4 (286). С. 90–101. DOI: https://doi.org/10.32752/1993-6788-2025-1-2.

18. Global economic prospects. *World Bank:* website. 2023. URL: https://www.worldbank.org/en/publication/global-economic-prospects (access date: 20.11.2025).

19. Review of maritime transport 2022. *UNCTAD:* website. 2022. URL: https://unctad.org/publication/review-maritime-transport-2022 (access date: 20.11.2025).

20. Shatun A. Socio-cultural factors of trust in East Asian business networks. *Актуальні питання економічних наук*. 2025. № 18. DOI: https://doi.org/10.5281/zenodo.18153254.

21. Shatun A. Optimization of global supply chains through models of friendly and regional localization of production. *Здобутки економіки: перспективи та інновації*. 2025. № 25. DOI: https://doi.org/10.5281/zenodo.18084886.

22. Табакова Н. І. Багаторівневі моделі управління блокчейн-інфраструктурою у сфері розрахунків і платежів. *Здобутки економіки: перспективи та інновації*. 2025. № 24. DOI: https://doi.org/10.5281/zenodo.17647784.

23. Tabakova N. Synergy of artificial intelligence and blockchain in optimizing financial transactions and real-time auditing. *Актуальні питання економічних наук*. 2025. № 17. DOI: https://doi.org/10.5281/zenodo.17642066.

24. Табакова Н. І. Regulatory architecture for systemic risk control in decentralized financial ecosystems. *Наукові записки Львівського університету бізнесу та права*. 2025. № 46. С. 193–203. DOI: https://doi.org/10.5281/zenodo.17532896.