Olga Sushko[*1], Marina Efimova[2]

The Structure of Price Dynamics for Timber Products on World and Russian Markets

Struktura dinamike cijena drvnih proizvoda na svjetskome i ruskom tržištu

ORIGINAL SCIENTIFIC PAPER
Izvorni znanstveni rad
Received – prispjelo: 24. 8. 2025.
Accepted – prihvaćeno: 12. 2. 2026.
UDK: 630*88
https://doi.org/10.5552/drvind.2026.0289

ABSTRACT • *This research endeavor seeks to address the scientific challenge of discerning recurring patterns of price fluctuation in both international and national markets for timber and other forest-derived goods. Databases on prices for forest products have been created, which required careful processing and structuring of the data obtained: the information is structured into tables; search systems and visualization of dashboards in excel have been implemented; regular updates are carried out. Based on the created databases on prices for forest products, time series of prices with different interval time lags (monthly average, quarterly average and annual average) have been developed, considering market segments. The primary statistical analysis of price time series with the definition of statistical indicators was carried out. A comprehensive analysis of the data obtained from various sources allowed us to compile a detailed picture of the price dynamics of forest products, namely to: Determine the structure of the dynamics of prices for forest products; Identify promising areas of activity, taking into account the growing demand for certain types of forest products and the reduction in consumption of other types of products; Predict price dynamics: knowing the trends in prices for forest products allows enterprises to more accurately forecast their profits and plan investments; Assess the competitiveness of Russian timber products in the domestic and global markets.*

KEYWORDS: *price policy; prices; forestry; forecasting and simulation: models and applications; methodology for collecting, estimating, and organizing macroeconomic data*

SAŽETAK • *Predmet ovog istraživanja bio je znanstveni izazov prepoznavanja ponavljajućih modela fluktuacije cijena na međunarodnome i nacionalnom tržištu drva i ostalih drvnih proizvoda. Izrađene su baze podataka o cijenama drvnih proizvoda, što je zahtijevalo pomnu obradu i strukturiranje dobivenih podataka. Informacije su svrstane u tablice, implementirani su sustavi pretraživanja i vizualizacije tablica u Excelu te su provođena redovita ažuriranja. Na temelju izrađenih baza podataka o cijenama drvnih proizvoda razvijeni su vremenski nizovi cijena uzimanjem u obzir tržišnih segmenata različitih vremenskih intervala (mjesečnog prosjeka, tromjesečnog prosjeka i godišnjeg prosjeka). Provedena je primarna statistička analiza vremenskih nizova cijena s definicijom statističkih pokazatelja. Sveobuhvatna analiza podataka dobivenih iz različitih izvora omogućila nam je sastavljanje detaljne*

* Corresponding author
[1] Author is researcher at Russian University of Economics named after G.V. Plekhanov, MGTU GA, Moscow, Russia. https://orcid.org/0000-0003-0865-6621
[2] Author is researcher at Russian University of Economics named after G.V. Plekhanov, Moscow, Russia. https://orcid.org/0000-0002-1340-8406

slike dinamike cijena drvnih proizvoda, kao i utvrđivanje strukture dinamike cijena drvnih proizvoda; identificiranje obećavajućih područja djelovanja uključivanjem i rastuće potražnje određenih vrsta drvnih proizvoda i smanjenja potrošnje drugih vrsta proizvoda; predviđanje dinamike cijena (poznavanje trendova cijena drvnih proizvoda omogućuje poduzećima da točnije predvide svoju dobit i planiraju ulaganja) te procjenu konkurentnosti ruskih drvnih proizvoda na domaćemu i svjetskom tržištu.

KLJUČNE RIJEČI: *politika cijena; cijene; šumarstvo; predviđanje i simulacija: modeli i primjene; metodologija prikupljanja, procjene i organiziranja makroekonomskih podataka*

1 INTRODUCTION
1. UVOD

Fluctuations in prices for forestry products (logging, woodworking, pulp and paper industry, plate production) are a complex and multifaceted problem affecting both producers and consumers and the economies of exporting countries.

The main problems caused by these fluctuations are:

1. For enterprises of the forestry complex:

- The impossibility of long-term planning: Sharp price spikes make it difficult to invest in modernization, expansion of production, and development of new products.
- Reduced profitability and loss risks: Falling prices for finished products with fixed or rising costs for raw materials, energy and logistics lead to financial losses. • Problems with contract fulfillment: Long-term supply contracts become risky, as the price at the time of execution may differ significantly from the price at the time of conclusion.
- Shortage of working capital: During periods of low prices, revenue decreases, which leads to a shortage of money for salaries, taxes and purchases of raw materials.

2. For end users and related industries (construction, furniture industry, retail):

- Unpredictability of project costs: Spikes in prices for lumber, plywood, and slabs make it impossible to accurately estimate construction costs.
- Decrease in demand: A sharp rise in prices (as it was in 2021-2022) can “freeze” demand for housing and repairs, which affects the entire chain.
- Search for substitutes: Consumers are starting to look for alternative materials (plastic, metal, composites), which can lead to an unrecoverable wood market loss.

3. For the economies of exporting countries (for example, Russia, Finland, Canada):

- Instability of foreign exchange earnings: Timber exports are an important source of income. Price fluctuations create instability in the trade balance and budget.
- Regional destabilization: Many forest regions of Russia are monospecialized, therefore, falling prices lead to unemployment and social problems.

The main reasons for fluctuations in prices for timber products:

A) Cyclical and market factors:

1. Macroeconomic situation: Global and national crises, economic growth/recession rates (especially in key consumer countries: USA, China, EU). Construction boom or bust.

2. Seasonality: The demand for building materials increases in spring and summer, which affects prices.

3. Changes in exchange rates: For export-oriented industries (like Russia), the strengthening of the national currency reduces profitability in local terms.

4. Energy prices and logistics: The timber industry is energy- and transport-intensive. Rising fuel and freight prices directly affect the cost.

B) Industry and structural factors:

5. Supply and demand imbalance: Fires, bark beetle outbreaks, and epidemics of forest diseases (as in Europe) reduce the supply of raw materials and inflate prices. On the other hand, overproduction (for example, after restrictions are lifted) leads to a collapse in prices.

6. Policy decisions and trade barriers:

- Export duties and quotas (as in Russia) artificially limit supply on the world market, affecting prices.
- Trade wars and sanctions (sanctions against Russian timber in the EU) dramatically reshape logistics chains, creating shortages in some regions and oversupply in others.
- Environmental regulations (FSC requirements, logging bans) increase costs and limit the raw material base.

C) Speculative factors:

7. Stock trading: Prices for some timber (for example, lumber) are formed on commodity exchanges (for example, CME), where not only real supply/demand, but also the actions of financial investors and hedge funds play an important role.

The topic of price fluctuations in the timber market has become particularly relevant in recent years. These are no longer just cyclical changes, but the result of a complex interweaving of global and local factors, which is confirmed by reports from industry analytical agencies and consulting companies (practical data and forecasts). The FAO (Food and Agriculture Organization of the United Nations) (FAO, 2024) and the United Nations Economic Commission for Europe (UNECE,

2024) publish forest market surveys (FAO Forestry) and statistics. ITTO (International Tropical Timber Organization, 2026) provides monthly market reports, especially on tropical timber. Leading global analytical agencies in the field of forestry such as Forest Economic Advisors (FEA, 2026), RISI (Fastmarkets, 2025), and Wood Resources International (WRI, 2026) publish reports, reviews, and press releases on trends in the forest products market.

Deloitte's "2024 forestry industry outlook" indicates that volatility has become the "new normal" (Deloitte, 2024). Companies are encouraged to invest in digitalization and data analysis for better forecasting. PwC in the Global Forest report, Paper & The Packaging Industry Survey notes that the main risks for the industry remain macroeconomic instability, energy costs and supply chains, which directly supports the thesis of ongoing price fluctuations (PwC, 2026).

Analytical agencies (Fastmarkets, RISI) in their weekly and monthly market reports constantly contain statements like "the market is looking for balance," "uncertainty persists," "prices are showing mixed dynamics," which is direct evidence of instability. The current analytical picture fully confirms our thesis – not "just fluctuations", but "structural volatility" – this is the term that experts are increasingly using. The timber products market has become a complex system where traditional factors (supply and demand) are reinforced by extreme external shocks (geopolitics, climate disasters, global inflation).

An accurate forecast of price dynamics in the Russian forest industry requires an understanding of the broader global context in which the domestic market operates. Developments in the world market for forest products shape external economic conditions, trade restrictions and demand trends that indirectly affect pricing mechanisms within Russia. Therefore, an analysis of the global market environment is an important analytical prerequisite for subsequent forecasting of prices in the Russian forest sector.

The purpose of scientific research is to develop adaptive models for forecasting prices for forest products. Achieving this goal involves solving a number of interrelated tasks, including analyzing retrospective data on prices for major types of forest products, identifying key factors influencing their dynamics, and developing mathematical models that can take into account the complex relationships between these factors. Special attention was paid to the study of the impact of macroeconomic indicators, such as inflation rates, currency exchange rates and the geopolitical situation, on pricing in the forestry complex. An important aspect of the research is to take into account the specifics of individual segments of the timber products market, such as lumber, pulp, paper and wood boards, since each of them has its own unique characteristics and is influenced by various factors. The results of the study will form the basis for the development of practical recommendations for forestry enterprises on managing risks associated with price volatility and optimizing planning and production strategies. The created forecasting models will make it possible to make more informed decisions in the field of pricing, procurement of raw materials and investments in new technologies. The research objectives included: to analyze modern theoretical approaches to forecasting prices for forest products; to collect, process and analyze statistical data on prices for key types of forest products; to analyze modern approaches to forecasting prices for forest products; to collect, process, and analyze statistical data on prices; to identify trends, cyclical and seasonal components of price dynamics using econometric and spectral methods; and to assess price volatility and structural features of time series. Adaptive forecasting models (such as ARIMA models) are considered a promising direction for further research to develop practical recommendations on the application of adaptive models for timber companies and industry management bodies.

Thus, the implementation of scientific research will make a significant contribution to the development of the theory and practice of forecasting prices for forestry products and will help to increase the competitiveness of the industry in the global market.

2 RELEVANCE OF THE RESEARCH
2. RELEVANTNOST ISTRAŽIVANJA

Various econometric methods are used in the study and forecasting of indicators. However, now, the use of adaptive methods for predicting one-dimensional time series is becoming the most popular (McConnell *et al*., 2021; Shiller, 2020; International Monetary Fund, 2020). Understanding the dominant current trend, rather than the overall average trend across a given timeframe, is crucial because it holds the most significant influence on the process in question. This allows you to more accurately predict the future values of the time series and take into account changes in its dynamics. For this reason, the information of the deadline period becomes the most relevant. Adaptive time series forecasting methods are relevant and widely used in various fields because they allow you to take into account changes in time series and predict their future values. They make it possible to obtain more accurate forecasts compared to other methods, such as static models, which do not take into account changes in the dynamics of the series (Dzerjinsky *et al*., 2020: McConnell *et al*., 2021; Medvedev *et al*., 2022). Furthermore, adaptive methodologies prove valuable in process quality analysis and control, price forecasting for products and services, and financial market analysis. The essence of adaptive forecasting methods is that they take into account the different informational significance of the time series levels through a system of weights determined depending on the novelty of data. Adaptive models are based on moving average and autoregression schemes. The estimation of the coefficients of the adaptive model is based on a recurrent method, which avoids the re-calculation of all calculations when new data becomes available. In this case, the model is adapted iteratively. The forecasting model incorporates a mechanism for adjusting predictions based on real-world data. When actual data points become available, the discrepancy between these and the previously predicted values is calculated as the forecast error. This error term is then integrated back into the model, influencing its transition to subsequent states and thereby refining future predictions. The next step is to change the parameters to ensure a greater degree of consistency between the behavior of the model and the dynamics of the series. The final stage is to determine the forecast value for the future period. The described process is iterative, which helps the adaptive model to regularly receive up-to-date data, adapt to them and reflect the current direction of development. Adaptive methods are well suited for short-term forecasting one or more steps ahead. Adaptive forecasting of economic processes plays a key role in modern economic analysis, increasing the accuracy of forecasts in conditions of instability and uncertainty. Over the past twenty years, similar methods have been actively developed in Russian practice, due to the need for flexible planning in conditions of frequent economic crises. The use of adaptive models allows taking into account the dynamics of changing factors and timely response to them.

Choosing the optimal forecasting method is a critically important aspect of predictive analytics and presents a significant challenge in academia. Modeling and forecasting of socio-economic trends have a rich history (Landsberg *et al*., 1965; Meadows *et al*., 1991; Pestel, 1994; Starikov *et al*., 2022). In the XX and XXI centuries, there has been increased interest in this field, which has led to increased requirements for the rigor of methodology and scientific validity of approaches. Economists from both the United States and Europe are actively involved in large-scale forecasting projects. An example is the study by G. Landsberg, L. Fishman and J. Fischer's "Resources in America's Future: Needs and Opportunities to Meet Them, 1960-2000." (Burdakova *et al*., 2023; Dewhurst *et al*., 1961; Kondratiev *et al*., 2003).

New publications on forecasting methods include a significant number of works on forecasting prices of non-oil and gas, financial instruments, and currencies. Special attention is paid to the development and application of new mathematical models and algorithms for forecasting. Neural networks, machine learning methods, and hybrid approaches combining traditional statistical methods with modern IT technologies are showing promising results. Big Data analysis is also an important area, which makes it possible to identify hidden patterns and correlations that can be used to improve the accuracy of forecasts. K. A. Saprykin considered various methods for predicting the price of URALS gray oil, including statistical methods such as autoregressive integrated moving average models, exponential smoothing. The author also introduced new machine learning methods (linear regression, support vector machines, artificial neural networks, long-term short-term memory) (Saprykin, 2023). A group of scientists D. Orazmukhamedov, K. Tyachmuradov, M. Nurmukhammedov, M. Rakhmanov evaluated various approaches to forecasting in conditions of uncertainty and market volatility, including econometric models, time series methods and machine learning (Orazmuhammedov *et al*., 2024). The authors have substantiated the advantages and disadvantages of different forecasting methods, as well as their practical application. The author focused on the accuracy of forecasts of various models and their adaptability to changing market conditions (Azarnova *et al*., 2025). T. V. Azarnova, N. G. Asnina, A. I. Kolosov, A.V. Lependin used machine learning methods to predict the consumer price index: PyAF, StatsForecastAutoARIMA, Prophet, recurrent neural networks LSTM (Azarnova *et al*., 2025). S. V. Veretekhina used different theories (dynamic systems, price behavior of Dow, fractals, sets) to predict the average price of exported goods and mathematical analysis. To assess the persistence of the series, the Hurst coefficient was calculated (Veretekhina, 2025). V. D. Yezhkin and M. V. Radionova applied machine learning and neural network methods to build models and select the best model to obtain predicted Bitcoin price values (Yezhkin and Radionova, 2024). The topic of forecasting oil prices is also presented in the work of A. P. Samatova and I. V. Filimonova. The paper provides an overview of methods for forecasting oil prices. It is shown that the existing methods of forecasting oil prices can be divided into quantitative and qualitative methods. The main limitations of the existing approaches are revealed, the advantages and disadvantages of the most popular methods are shown. The classification of machine learning methods is presented (Samatova and Filimonova, 2025).

In the present study, adaptive forecasting methods are discussed as an important methodological background. However, the empirical analysis focuses on identifying the structural components of price dynamics (trend, cycles, seasonality and volatility) rather than on producing adaptive short-term forecasts.

3 THEORETICAL REVIEW OF STUDIES
3. TEORIJSKI PREGLED ISTRAŽIVANJA

In the 1970s, outstanding researchers, J. P. Morgan and D. Meadows, made a significant contribution to the development of global forecasting (Shvets *et al.*, 2020). Their fundamental work "Limits of Growth" introduced the concept of "models of system dynamics" to the scientific community. Mesarovich and Pestel were the first to apply an innovative methodological approach that made it possible to analyze the interrelationship of the main regions of the world (Deng *et al*., 2022). By the mid-1980s, more than fifteen international scientific forecasts, called "models of the world," had been distributed. At the end of the 20th century, there was a revival of interest in forecasting long-term socio-technological trends for periods from 50 to 1000 years. In this area of research, the work of authors such as Nesbitt and Eburdin has spread ("What awaits us in the 90s: megatrends. 2000) and Peterson ("The Path to 2015"). The contributions of the scientists such as J.F. Coates, J.B. Mahaffy, and E. Hines, among others, deserve recognition and further study (Kim *et al*., 2024). In the final period of the twentieth century, there was a significant increase in the use of mathematical modeling, which was due to rapid progress in the field of information technology and the creation of advanced software products. Modern information technologies and computational methods provide researchers with the opportunity to conduct in-depth analysis of complex phenomena and processes. The increasing negative trends emphasize the importance of developing accurate and reliable forecasts based on mathematical modeling.

The intricate nature of current forecasting tools and methodologies presents significant challenges. Selecting the most appropriate method and assessing the trustworthiness of the resulting predictions pose persistent dilemmas. Scientists express concern that a major drawback across various forecasting systems lies in the lack of transparency regarding their methodologies. In most instances, detailed descriptions of the forecasting methods employed are absent. Due to the complexity of forecasting models, it is extremely difficult to ascertain the precise cause of any discrepancies between predicted and actual outcomes. We cannot definitively determine whether such deviations result from limitations within the model's structure or methodology, or from unforeseen external factors (Federal State Statistics Service, 2024; UNECE/FAO, 2021; U.S. Department of Labor, Bureau of Labor Statistics, 2020). The inherent intricacy of most economic processes often defies accurate representation through simple mathematical functions, necessitating the development of more sophisticated models capable of addressing this complexity.

The field of modeling and forecasting employs a variety of methodologies. Given its practical importance, it is crucial to share ongoing scientific research and knowledge. Both governmental and private entities dedicate substantial resources and expertise to advance this domain, driving both theoretical and applied progress.

Forecasting methods are divided into quantitative and qualitative ones. The forecasting methodology is selected based on the nature of the task, the volume and quality of the available information, as well as the objectives of the forecast (FAOSTAT, 2024.; UNECE/FAO, 2021). Quantitative forecasting methods rely on mathematical and statistical analysis of historical data to identify patterns and trends that can be used to estimate future values. Quantitative methods rely on numerical data and mathematical models. Examples include time series analysis for identifying patterns in historical data, extrapolation for projecting trends, regression analysis for establishing relationships between variables, and Monte Carlo simulation for modeling probabilities and uncertainties. Qualitative methods, conversely, leverage expert knowledge and insights. These approaches are particularly valuable when data is scarce or subject to significant uncertainty. Notable qualitative techniques encompass the Delphi method, which employs structured questionnaires to gather consensus from a panel of experts; brainstorming, which encourages creative idea generation within a group setting; and focus groups, where moderated discussions facilitate the exploration of opinions and perspectives among a targeted audience.

However, the subjective nature of qualitative methods and their limited capacity to capture dynamic changes in economic systems constrain their applicability in the analysis of time-dependent processes. As economic environments become increasingly volatile and data availability improves, the need arises for forecasting approaches that can incorporate new information and adjust to evolving conditions in a systematic and formalized manner. In this context, adaptive forecasting methods are employed.

Adaptive forecasting methods are defined as approaches that allow the construction of self-correcting (self-adjusting) economic and mathematical models capable of rapidly responding to changing conditions by taking into account the results of previous forecasts and considering the differing informational value of time-series observations. In the scientific literature, adaptive forecasting encompasses a broad range of approaches based on exponential smoothing, autoregressive relationships, and various modifications of moving averages, as well as other methods aimed at

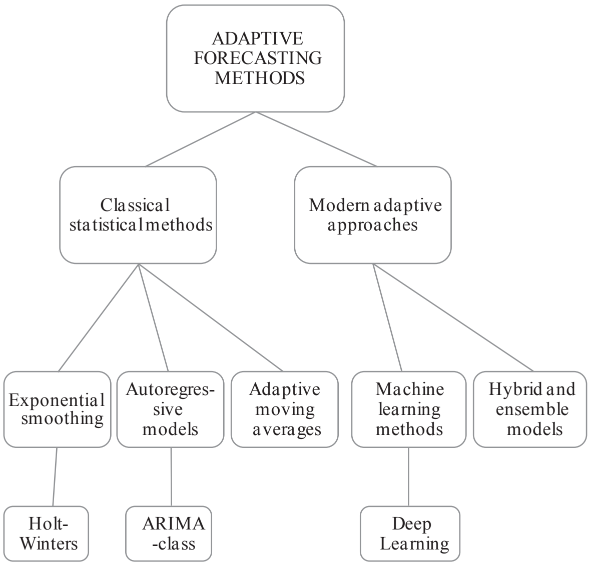

Figure 1 Classification of adaptive forecasting methods: compiled according to Pyzhyev (2024) and Shiller (2020)
Slika 1. Klasifikacija adaptivnih metoda predviđanja: sastavljeno prema Pyzhyev (2024.) i Shiller (2020.)

capturing trend-related and dynamic components of economic time series.

The main groups of adaptive forecasting methods discussed in the literature are summarized in Figure 1.

The peculiarity of adaptive methods is that they are able to take into account changes in the studied processes and adapt to them. With exponential smoothing, the time series is determined by a weighted moving average. This method has several modifications: simple exponential smoothing, the Holt method (double exponential smoothing) for series with a trend, and the Holt-Winters method (triple exponential smoothing) for series with a trend and seasonality. Autoregression is based on the fact that future values of a time series are calculated based on previous observations of the same series. The current value of a variable is explained by its previous values and a random deviation. Polynomial models are used if it is assumed that the trend of a process can be described by a polynomial of degree n, then the coefficients of the predicting polynomial are calculated using exponential averages of the corresponding orders. Another important group of adaptive methods includes autoregressive and autoregressive moving average models, particularly ARIMA-class models. These models combine autoregressive components, differencing procedures to achieve stationarity, and moving-average terms to account for random shocks. ARIMA models are capable of capturing both inertia and stochastic fluctuations in time series and are widely applied in price forecasting and macroeconomic analysis. However, their effectiveness depends on strict assumptions regarding stationarity and error structure. With a moving average, the actual levels of the time series are replaced by calculated levels that are less susceptible to fluctuations. The main types of moving averages that are used in adaptive forecasting are simple moving average, adaptive moving average. Among the current trends in statistical forecasting, we can single out the following methods: hybrid models and ensembles – combining various approaches (statistical methods, machine learning, expert assessments) into a single predictive system; deep learning for time series – using specialized neural network architectures (LSTM, GRU, transformers) to model complex nonlinear dependencies in data with long-term patterns; causal modeling is the transition from correlation models to causal ones, which make it possible not only to predict, but also to model the effects of interventions in the system.

Despite their advantages, adaptive forecasting methods vary significantly in terms of transparency, data requirements, and interpretability. Therefore, the choice of a specific adaptive method should be determined by the research objectives, data availability, and the balance between model complexity and analytical clarity. In the present study, adaptive forecasting methods are considered as an important theoretical foundation and a promising direction for further research, while the empirical analysis focuses on identifying the structural components of price dynamics using trend, cyclical, and volatility analysis.

4 RESEARCH OBJECTIVES AND METHODS
4. CILJEVI I METODE ISTRAŽIVANJA

Monitoring prices for forest products is especially relevant in conditions of global economic instability, when factors such as changes in raw material prices or environmental influences can significantly affect the cost of products. The analysis and calculation indicators required statistical materials from the Russian state services (Azarnova *et al*., 2025). This analysis utilizes a comprehensive range of data sources to ensure its accuracy and reliability. Information regarding forest resources and management practices was drawn from the Federal Forestry Agency, as well as statistical databases and reports published by international organizations such as the European Commission, the World Bank, the International Institute for Sustainable Development, FAOSTAT, UNEP, and UNCTAD (Samatova and Filimonova, 2025; Shvets *et al*., 2020; Veretekhina, 2025; Yezhkin and Radionova, 2024). Regional integration associations have also provided data for this analysis. Furthermore, insights from specialized industry organizations and associations provided valuable context and perspective. Thus, the analysis of data obtained from various sources allows us to obtain a complete picture of the price dynamics for the products of the forest complex. Calculations and price estimates were made in the national currency of Russia (ruble). A similar study was also conducted by the authors regarding world prices for forest products; however, it was not possible to compare the results in this article due to the limited scope of the research.

At the initial stage of the study, preliminary processing of the raw data was carried out, including checks of the time series for completeness, homogeneity, and the presence of anomalous values. Missing observations were adjusted using interpolation methods while preserving the original logic of price dynamics. To eliminate the effects of heterogeneous time intervals, the raw data were aggregated into monthly, quarterly, and annual series depending on the objectives of the analysis and the specific characteristics of each product category. All time series were converted into a comparable format, which made it possible to correctly analyze price dynamics across different segments of the forest products market.

After the initial data processing, a preliminary statistical examination was carried out in order to reveal the main features of price behavior. At this stage, basic descriptive indicators were computed, such as average values, measures of variability, standard deviation, and the coefficient of variation, which made it possible to evaluate both the magnitude and intensity of price instability for individual product categories. On the basis of these results, products were provisionally grouped according to their volatility levels, allowing the most risk-sensitive segments of the market to be identified. The subsequent phase of the research focused on the structural analysis of price time series. To achieve this, decomposition techniques were employed to separate long-term trends, seasonal effects, cyclical movements, and random disturbances. Trend dynamics were assessed using regression methods, while the reliability of the estimated parameters was verified through standard statistical tests, including the t-statistic and the coefficient of determination.

The seasonal component was analyzed by comparing intra-annual price fluctuations, while cyclical movements were identified based on an analysis of medium-term deviations from the long-term trend.

To conduct a more in-depth examination of the periodicity of price fluctuations, spectral analysis was employed, making it possible to identify hidden frequency characteristics of the time series. The use of this method allowed dominant cycles to be determined and their stability over time to be assessed. Spectral estimates made it possible to compare the frequency structure of prices for different product types and to identify similarities or differences in the mechanisms underlying price dynamics in domestic and global markets.

Within the framework of the empirical analysis, trend–cyclical decomposition, linear regression modeling, and spectral analysis were applied to study price dynamics. These methods were used to identify long-term trends, cyclical patterns, and volatility characteristics of forest product prices. Prior to model estimation, the stationarity of the series was tested, and differencing procedures were applied when necessary. Model parameters were selected based on information criteria and the quality of approximation, while model adequacy was assessed through residual analysis and retrospective forecast validation. The use of adaptive approaches made it possible to account for changes in the market environment and for the weakening stability of traditional relationships under external shocks.

As one of the widely used adaptive forecasting approaches discussed in the literature, ARIMA models can be described as follows (Eq. 1):

$$yt = \alpha + \varphi 1yt-1 + ... + \varphi pyt-p + \varepsilon t + \theta 1\varepsilon t-1 + ... + \theta q\varepsilon t-q \quad (1)$$

ARIMA models use three different parameters: p, d, and q.

These parameters define the structure of the model and allow it to take into account seasonal fluctuations, trends, and noise components of the data. The model is written as ARIMA (p, d, q).

The parameter p is the autoregressive order. It determines how much the current values of the time series are related to its past values. Thanks to this, you can adjust the model based on the use of previous data. For example, if the last three days were hot, then tomorrow will most likely also be warm.

The parameter d denotes the degree of integration, which helps to eliminate the trend and make the time series stationary. The smaller the difference between the current and previous values, the easier it will be to predict the future – for example, temperature, if the difference over the last three days is minimal.

The q parameter is associated with the moving average and describes the impact of past prediction errors on the current result. It allows the model to take into account noise deviations and adjust predictions based on past errors.

The final stage of the methodological procedure involved synthesizing the results of the quantitative analysis and interpreting them in the context of the functioning of the forest sector. The estimates obtained were used to compare price dynamics across different product groups, identify general patterns, and determine specific features of individual market segments. The integrated application of statistical, econometric, and spectral methods ensured a comprehensive approach to analyzing prices for forest products and provided a methodological basis for further forecasting and the development of practical recommendations.

In this study, ARIMA models are not directly estimated; the description is provided to illustrate potential directions for further model development.

The study of data obtained from various sources allowed us to create a detailed picture of the price dynamics for the products of the forest complex:

- Identify promising areas of activity: taking into account the growing demand for certain types of forest products allows you to focus on the development of production of these types of products.
- Understanding pricing trends within the forestry industry empowers businesses to make more precise profit projections and formulate well-informed investment strategies.
- Knowledge of pricing fluctuations in the forestry sector enables companies to develop more accurate profitability forecasts and make sound investment decisions.

5 RESULTS OF ANALYSIS
5. REZULTATI ANALIZE

The results presented below correspond to the applied trend-cyclical and regression-based analytical framework and do not represent adaptive forecast outputs. During the analyzed period, there has been a significant fluctuation in prices for round softwood lumber for sawing and planing on the Russian market, which can be attributed to several key factors (Ryabova *et al*., 2020). Fluctuations in the demand for construction materials, driven by economic factors and evolving regulations concerning forestry practices, have significantly influenced market dynamics. Furthermore, geopolitical tensions and trade restrictions have introduced volatility into supply chains, subsequently impacting pricing strategies. For example, in 2018, there was an increase in prices for timber against the background of an increase in construction volumes. Since mid-2019, economic sanctions and revisions to export policies have led to a significant decline in exports of round softwood timber suitable for sawing and planing. Statistical data indicate that prices for this timber within the Russian market remained around 2500 per cubic meter throughout 2020. Since the beginning of 2021, prices for round softwood lumber for sawing and planing in the Russian market have begun to grow actively, and by the end of the 1st quarter of 2022 they increased by 50-55 % (Figure 2). Market conditions in the period of 2024-2025 are anticipated to be shaped by global events (Pyzhyev, 2024). Nevertheless, domestic developments such as enhanced logistics and sustainable production practices are expected to contribute to price stabilization within the softwood lumber market. In 2024, prices for softwood rose by 29 % on the domestic market. The analysis showed that the time series of monthly and quarterly lumber prices from 2003 to 2023 contain an increasing trend, cyclical and seasonal components. The trend parameters are estimated, and the statistical significance is verified using the coefficient of determination and the Fisher criterion. The statistical significance of the trend parameters is confirmed by hypothesis testing: the null hypothesis of a zero slope is rejected at the 5 % significance level, while the coefficient of determination indicates a satisfactory model fit. The equation of the increasing trend for the dynamics of world prices is: $y = 546.74 \cdot x + 11900$. The validity of the estimated trend is supported by a sufficiently high coefficient of determination (R^2), indicating that a substantial share of price variation is explained by the model. The slope coefficient is statistically significant according to standard hypothesis testing ($p < 0.05$). The equation of the increasing trend for the dynamics of monthly domestic prices for softwood lumber is: $y = 106.32 \cdot x + 3737.9$. In contrast to the dynamics of monthly domestic prices for lumber, the trend of annual price dynamics has a negative constant indicator. The cyclical component of the time series of lumber prices for the global market is determined by the period of 12-17 quarters. For the time series of prices for lumber for the domestic market in the period 1998-2023, it also amounts to 11-16 quarters. The main feature of the dynamics of time series of lumber prices is an increase in the amplitude of cycles after 2015. Seasonal fluctuations in prices on the global and domestic lumber markets are expressed slightly and are associated to a greater extent with the period of activity in the construction market.

Compared to July 1, 2024, in August 2024, prices for round softwood lumber for sawing and planing increased by 1279.61 rubles. The maximum increase was observed on August 1, 2024 (1279.61 rubles). The minimum increase was recorded on May 1, 2024 (-895.03 rubles). The rising cost of round softwood lumber intended for sawing and planing is decelerating, suggesting a reduction in demand for this material.

The analysis of the dynamics of lumber prices on the world market was carried out from 2003 to 2024. The specified timeframe was characterized by substantial volatility driven by multiple influences. These included shifts in supply and demand dynamics, economic downturns, and modifications to both legal frameworks and environmental regulations. At the beginning of the period under review, from 2003 to 2007, there was a steady increase in prices, provoked by high demand for building materials in developing countries. However, with the onset of the global financial crisis in 2008, lumber prices plummeted, which caused serious consequences for many producers. Since 2010, the market began to recover, and by 2018 prices had reached new records, helped by the recovery of the

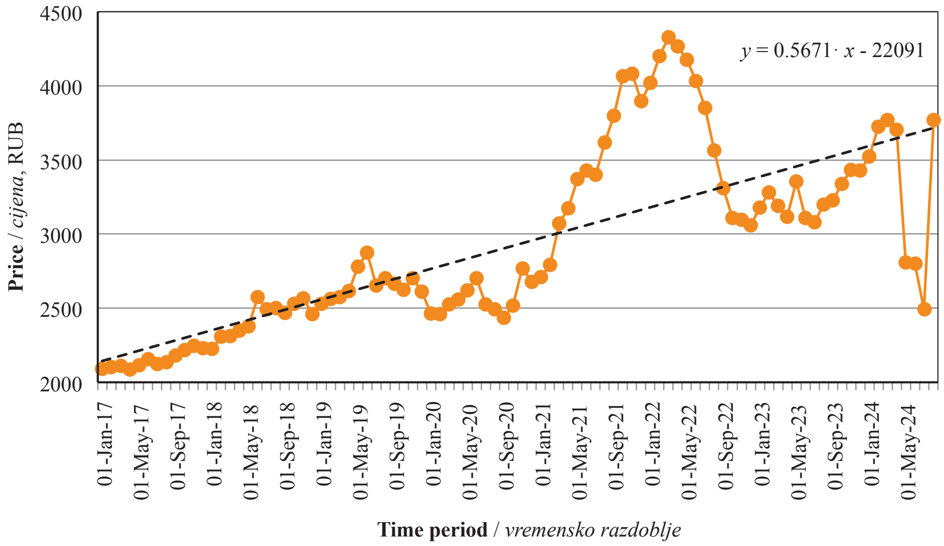

Figure 2 Prices for round softwood timber for sawing and planing on the Russian market (according to Federal State Statistics Service, 2024; FAOSTAT, 2024.; UNECE/FAO, 2021)
Slika 2. Cijene oblog drva četinjača za piljenje i blanjanje na ruskom tržištu (prema Federalnoj državnoj statističkoj službi, 2024.; FAOSTAT, 2024.; UNECE/FAO, 2021.)

construction sector and lack of resources. However, in 2020, the COVID-19 pandemic once again caused instability, which affected supply chains and demand. In 2023-2024, the market is showing signs of adaptation, but it is impossible to predict exactly how lumber prices will develop in an ever-changing global context. Lumber prices exhibited significant volatility between 2003 and 2024. The most substantial price increase was recorded in the fourth quarter of 2021, reaching 20,358 rubles. Conversely, the first quarter of 2022 witnessed a decline of 35,721 rubles, indicating a period of price reduction. The overall trend suggests an upward trajectory in lumber prices. By the second quarter of 2024, compared to the first quarter of 2003, prices had surged by 46,631 rubles, representing a 277 % increase. This data highlights a notable acceleration in the price dynamics of lumber during this period (Figure 3). In 2024, hardwood pilomaterialy prices rose by 77 % domestically.

A recent, extensive analysis examined global plywood pricing trends over a 21-year span, encompassing the years 2003 through 2024. During this period, there were significant price fluctuations caused by a variety of economic, political and environmental factors. From 2003 to 2007, there was a consistent increase in the cost of building materials. This price escalation was primarily attributed to a significant rise in demand, which was stimulated by the rapid growth of

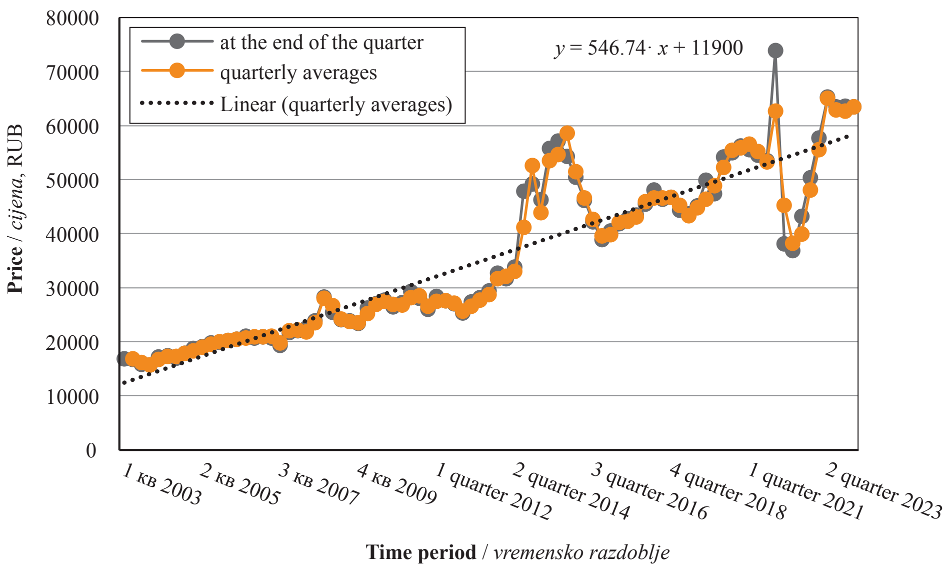

Figure 3 Prices for hardwood on the Russian market (according to Federal State Statistics Service, 2024; FAOSTAT, 2024; UNECE/FAO, 2021)
Slika 3. Cijene listača na ruskom tržištu (prema Federalnoj državnoj statističkoj službi, 2024.; FAOSTAT, 2024.; UNECE/FAO, 2021.)

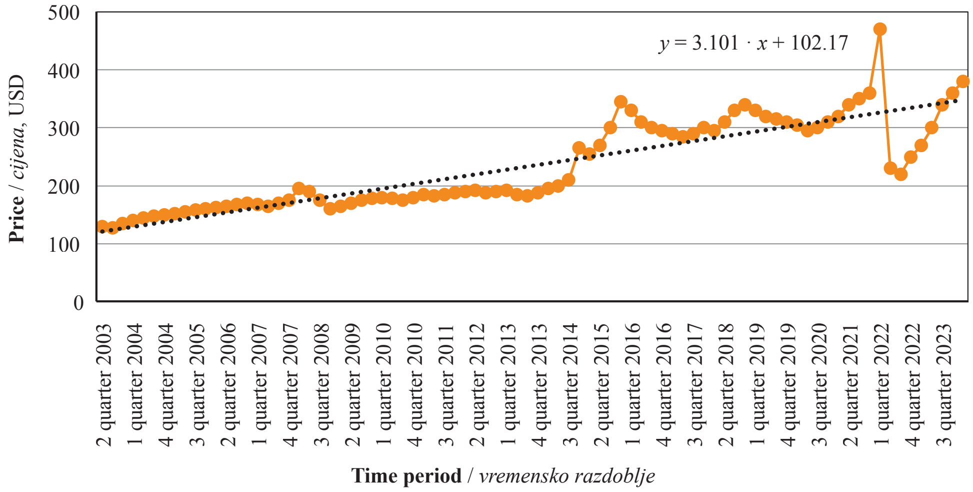

Figure 4 Prices of plywood on the world market (according to Federal State Statistics Service, 2024; FAOSTAT, 2024; UNECE/FAO, 2021)

Slika 4. Cijene furnirske ploče na svjetskom tržištu (prema Federalnoj državnoj statističkoj službi, 2024.; FAOSTAT, 2024.; UNECE/FAO, 2021.)

the construction industry in emerging economies. However, with the onset of the global financial crisis in 2008, there was a sharp drop in plywood prices, which caused an oversupply and the closure of many small and medium-sized enterprises. In the 2010s, the market gradually recovered, but the recorded growth was uneven. During the initial six months of 2019, inflationary pressures re-emerged. This resurgence was attributed to a confluence of factors, including elevated import tariffs and a scarcity of timber resources stemming from legislative modifications implemented by several nations. The prospects for 2023-2024 suggest further adaptation of the market to environmental standards and a growing interest in sustainable materials, which will have an impact on the pricing policy and the structure of offers in this niche. Plywood prices experienced their most significant surge in the second quarter of 2022, with an increase of 120.19 rubles. Conversely, the third quarter of 2022 witnessed the smallest price increase, a decrease of 242.04 rubles. The data indicates a sustained rise in plywood prices, suggesting that the rate of price increase is accelerating (Figure 4). In 2024, plywood prices increased by 21 % on the Russian market.

This study examined cellulose prices for NBSK (Europe, China, USA) and BHKP (in Europe and China). Data was sourced from the PIX index database, which provides weekly price measurements for various cellulose types. The time series data for both NBSK and BHKP demonstrate territorial comparability, encompassing a similar range of objects, consistent units of measurement, synchronized recording periods, and reliable reporting. Therefore, these samples are considered representative, allowing for conclusions drawn from the analysis to accurately reflect broader market trends within the cellulose industry. The maximum price increase is observed in Q1 2021 (200 USD), and the minimum increase is recorded in Q1 2019 (-121 USD). The rate of price increase in the analyzed dynamics shows that there are opposite trends in the dynamics of a number, which must be taken into account when developing a trend-cyclical price model. The study highlighted key trends reflecting changes in market value and production costs. In 2017, there was a steady increase in prices due to an increase in prices for raw materials and an increase in demand from the printing industry. From 2019 to 2021, there was a significant price fluctuation caused by global economic factors such as trade wars and instability in international markets. Manufacturers have adapted to the new conditions, eliminating excess costs and optimizing production processes. Since 2022, as the economy has emerged from the pandemic crisis, active price growth has resumed, due to increased consumption and the restoration of supplies (Figure 5). In 2024, wood cellulose prices decreased by 0.2 % on the domestic market.

The analysis of the dynamics of prices for offset paper of Russian manufacturers was carried out from 2017 to 2024. Forecasts for 2024 show positive changes, but risks remain associated with inflationary pressures and instability in the supply of key components. In August 2024, compared to July 2024, the price of offset paper decreased by 924.89 rubles. or by 1.3 %. The maximum increase is observed in May 2021 (2375.74 rubles). The minimum increase was recorded in 2020 (-2971.72 rubles). The rate of increase shows that the trend of the series is decreasing, which indicates a slowdown in the dynamics of prices for offset paper (Figure 6). The analysis showed that the time series of monthly and quarterly paper prices from 1998 to 2023 contain an increasing trend, cyclical and seasonal components. The main feature of the dynamics of time series of paper prices is an increase in the amplitude of

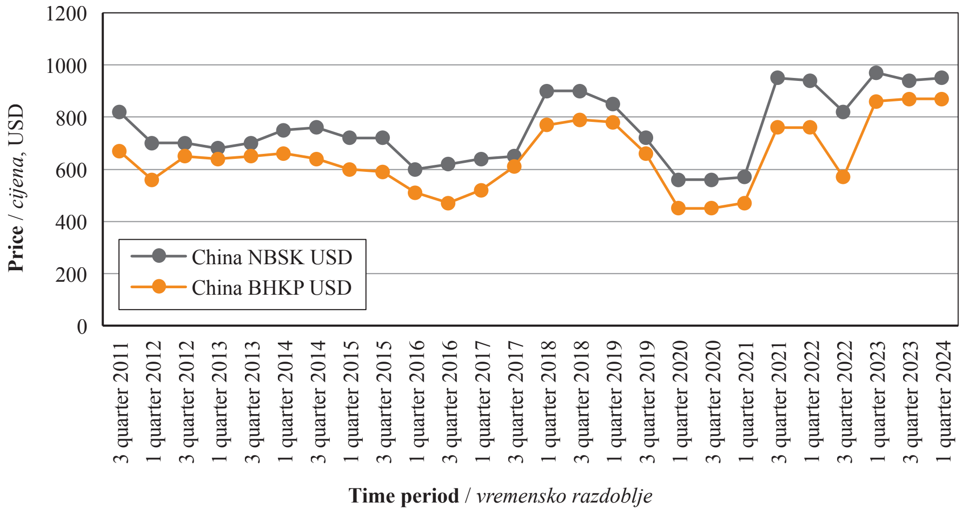

Figure 5 Prices of pulp on the world market (according to Federal State Statistics Service, 2024; FAOSTAT, 2024; UNECE/FAO, 2021)
Slika 5. Cijene celuloze na svjetskom tržištu (prema Federalnoj državnoj statističkoj službi, 2024.; FAOSTAT, 2024.; UNECE/FAO, 2021.)

cycles after 2015. Seasonal fluctuations in prices on the domestic paper market are not pronounced and are mostly associated with a period of activity in a number of consuming industries.

The analysis of the dynamics of prices for cardboard from Russian manufacturers was carried out from 2017 to 2024. During this period, there is a noticeable fluctuation in prices due to a variety of factors. In 2017-2019, cardboard prices had high volatility against the background of constant demand from the packaging industry and steady production rates. However, starting in mid-2020, against the background of global economic changes and volatility in commodity markets, there has been a sharp increase in prices. The COVID-19 pandemic, beginning in 2021, has substantially impacted the situation by causing disruptions to both manufacturing processes and supply chain operations. This increased competition for raw materials, which also affected the price dynamics. At the beginning of 2022, there is a repeated price spike associated with the restoration of demand for cardboard in the context of the global economic recovery. However, in 2023-2024, prices began to adjust again, as the market adapted to new conditions and consumer preferences changed. On August 1, 2024, compared to July 1, 2024, the price of cardboard from Russian manufacturers increased by 1555.3 rubles or by 2 %. The maximum increase is observed in January 2022 (18320.5 rubles). The minimum increase was recorded On January 1, 2020 (-14885.8 rubles). The rate of increase shows that the trend is increasing, which indicates an acceleration in prices for cardboard from Russian manufacturers (Figure 7). In 2024, kraft-liner cardboard prices rose by 7 %, while corrugated cardboard increased by 6 %.

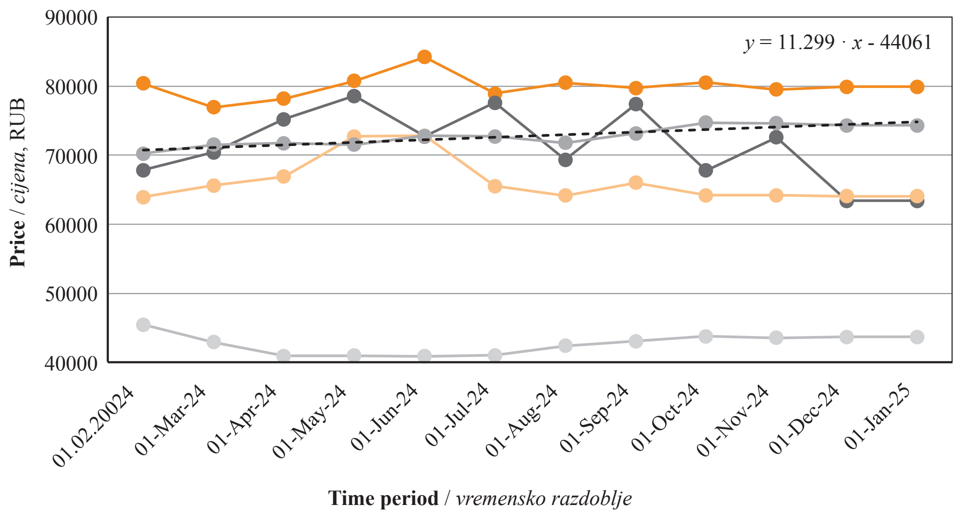

Figure 6 Prices for offset paper from Russian manufacturers, RUB/ton. (according to Federal State Statistics Service, 2024; FAOSTAT, 2024; UNECE/FAO, 2021)
Slika 6. Cijene ofsetnog papira ruskih proizvođača, RUB/t (prema Federalnoj državnoj statističkoj službi, 2024.; FAOSTAT, 2024.; UNECE/FAO, 2021.)

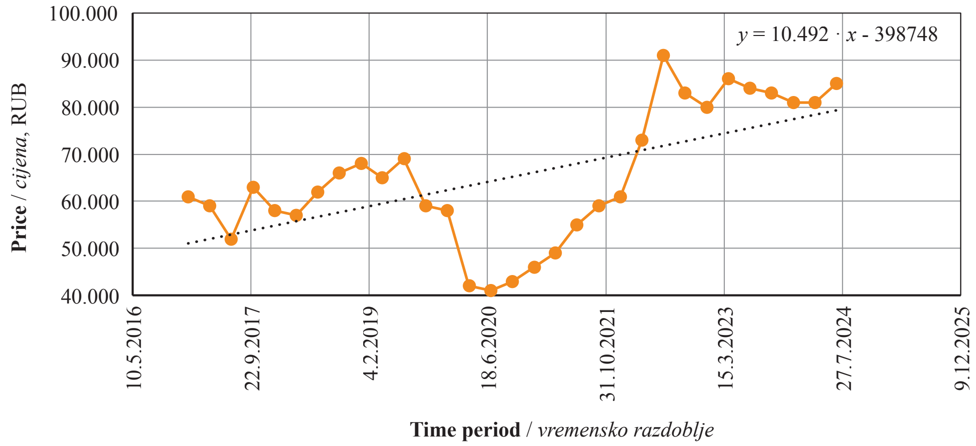

Figure 7 Prices of cardboard on the world market, RUB/ton (according to Federal State Statistics Service, 2024; FAOSTAT, 2024; UNECE/FAO, 2021)
Slika 7. Cijene kartona na svjetskom tržištu, RUB/t (prema Federalnoj državnoj statističkoj službi, 2024.; FAOSTAT, 2024.; UNECE/FAO, 2021.)

The study also examined price fluctuations in various product categories. This analysis reinforced the findings regarding the alignment and interconnectedness of domestic, export, and global prices. Specifically, it demonstrated that the pricing trends for forestry products exhibit a consistent and synchronized pattern, albeit occasionally with minor temporal discrepancies.

Based on the conducted analysis, key patterns in the price dynamics of major forest products were identified in both the Russian and global markets. Instead of repeating similar descriptions for each product, the main results are summarized in consolidated tables, which allows for a clear comparison of trend characteristics, cyclicality, and volatility. Analysis of monthly and quarterly time series from 2003 to 2023 (for some products from 1998 to 2023) revealed the presence of an increasing trend, cyclical, and seasonal components for most products. The main feature of price dynamics after 2015 is the increase in the amplitude of cycles. Seasonal fluctuations are weak and mainly associated with periods of activity in the construction sector and related industries. A compact visual summary of the quantitative analysis of price time series for five key categories of forest products is presented in Table 1. All trend coefficients are statistically significant at a level not lower than 5 %.

It is important to remember that price dynamics is a complex process that cannot always be predicted. One of the important aspects of the process of forecasting the dynamics of prices for forest products is the definition of its structure and the allocation of elements. The structure of price dynamics for timber products includes several elements, each of which has its own significance for understanding price changes in the market. The nature of the price dynamics structure is influenced by many factors, and understanding all the key elements of price dynamics will allow you to navigate the market more effectively and make more informed decisions (Table 2).

Forest product prices exhibit three recurring patterns over time: trend, seasonality, and cyclical fluctuations. These patterns can be mathematically represented as a function of these components, along with a random error term. This function can be expressed as $Yt = f(T, S, C, E)$, where Yt represents the observed price level at a given time point (t). The trend component (T) captures the long-term upward or downward movement in prices. The seasonal component (S) accounts for regular, predictable fluctuations that occur

Table 1 Summary of trend and cycle analysis results for key forest products
Tablica 1. Sažetak rezultata analize trendova i ciklusa za ključne drvne proizvode

Product *Proizvod*	**Trend equation ($y = bx + a$)** *Jednadžba linearnog trenda ($y = bx + a$)*	**Coefficient of determination (R^2)** *Koeficijent determinacije (R^2)*	**Statistical significance of trend (p-value)** *Statistička značajnost trenda (p-vrijednost)*
World lumber prices / *svjetske cijene drva*	$y = 546.74 \cdot x + 11900$	0.78	$p < 0.001$
Domestic softwood lumber prices *domaće cijene četinjača*	$y = 106.32 \cdot x + 3737,9$	0.65	$p < 0.01$
Domestic paper prices / *domaće cijene papira*	$y = 85.41 \cdot x + 12050$	0.71	$p < 0.001$
Pulp (global market) prices *cijena celuloze (globalno tržište)*	$y = 45.23 \cdot x + 8500$	0.60	$p < 0.05$
Plywood (global market) prices *cijena furnirskih ploča (globalno tržište)*	$y = 320.15 \cdot x + 10500$	0.69	$p < 0.01$

Table 2 Formatting sections, subsections and subsubsections
Tablica 2. Formatiranje odjeljaka, pododjeljaka i potpododjeljaka

Component *Komponenta*	**Classification** *Klasifikacija*	**Definition** *Definicija*	**Causes and duration of exposure** *Uzroci i trajanje izloženosti*
Trend – T	Systematic *sustavna*	A stable long-term trend *stabilan dugoročni trend*	The general economic situation with a duration of up to 20 years *opće gospodarsko stanje s trajanjem do 20 godina*
Cyclic – C *ciklička – C*	Systematic *sustavna*	Recurring ups and downs, going through 4 phases: depression, rise, peak, recession *ponavljajuća kretanja gore-dolje kroz 4 faze: depresiju, rast, vrhunac, recesiju*	The interaction of supply and demand factors with a duration of 8-14 sq. m. with varying intensity *međusobno djelovanje ponude i potražnje s trajanjem od 8 do 14 godina, uz različiti intenzitet*
Seasonal – S *sezonska – S*	Systematic *sustavna*	Regular periodic fluctuations occurring in the short term during the year *redovite periodične fluktuacije koje se pojavljuju kratkoročno tijekom godine*	Weather conditions, social habits, religious traditions throughout the year *vremenski uvjeti, društvene navike, religijske tradicije tijekom godine*
Irregular – E *neredovita – E*	Random *slučajna*	Residual fluctuation remaining after removal of systematic components *preostala fluktuacija nakon uklanjanja sustavnih komponenata*	Random unforeseen events. Short duration or delayed exposure *slučajni nepredviđeni događaji, kratko trajanje ili odgođeni učinak*

within a year. The cyclical component (*C*) represents longer-term cycles that extend beyond a single year. Finally, the random component (*E*) incorporates unpredictable, short-term variations in prices.

The following are the results of a spectral analysis of the prices of some types of forest products, conducted to identify hidden patterns and the frequency of data (Figure 8-12).

Based on the spectrum graphs, the frequency characteristics of time series of prices can be analyzed for each product. The peaks on the graph correspond to the frequencies that are most pronounced in the data. Higher amplitudes at low frequencies may indicate long-term trends, while higher amplitudes at higher frequencies may indicate short-term fluctuations or seasonality. Higher amplitudes at higher frequencies indicate short-term fluctuations or seasonality, e.g., 12-month cycles linked to seasonal harvesting constraints (winter logging reductions in northern regions) or annual construction peaks. The identified 11-16 quarter cycles (3-4 years) align with economic drivers like construction boom-bust cycles, influenced by real estate markets or recessions (post-2008 recovery patterns), and supply disruptions from environmental regulations or trade policies in the forest sector. These cycles may continue into 2024-2025, with production forecasts indicating modest growth in softwood biomaterial (+2 %) but decline in hardwood (-10 %).

Trend, seasonality, cycles and noise in the dynamics of prices for forest products are interrelated and can enhance or weaken each other's effect. The connectedness and mutual influence of the elements of price dynamics for forest products in retrospect and perspective is also changing. Some elements manifest themselves more strongly in historical periods and may weaken in the future. The impact and interaction of elements on the structure of price dynamics for forest products in retrospect and in the future can be represented as follows.

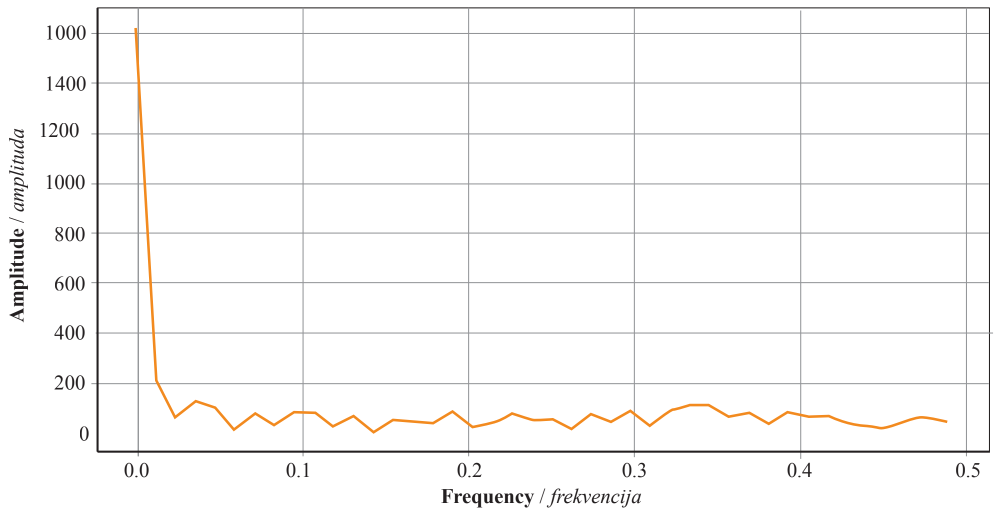

Figure 8 Range of product prices: Corrugated cardboard in rolls or sheets (compiled by the authors based on calculations performed)
Slika 8. Raspon cijena za valoviti karton u rolama ili listovima (sastavili autori na temelju provedenih izračuna)

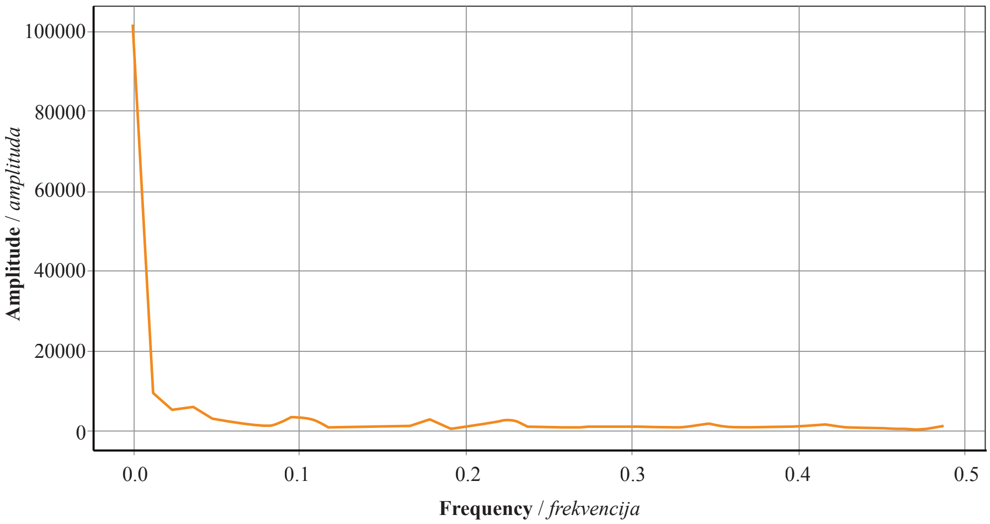

Figure 9 Range of product prices: Round hardwood timber for the production of pulp and wood pulp (compiled by the authors based on calculations performed)
Slika 9. Raspon cijena za oblo drvo listača za proizvodnju celuloze i drvne pulpe (sastavili autori na temelju provedenih izračuna)

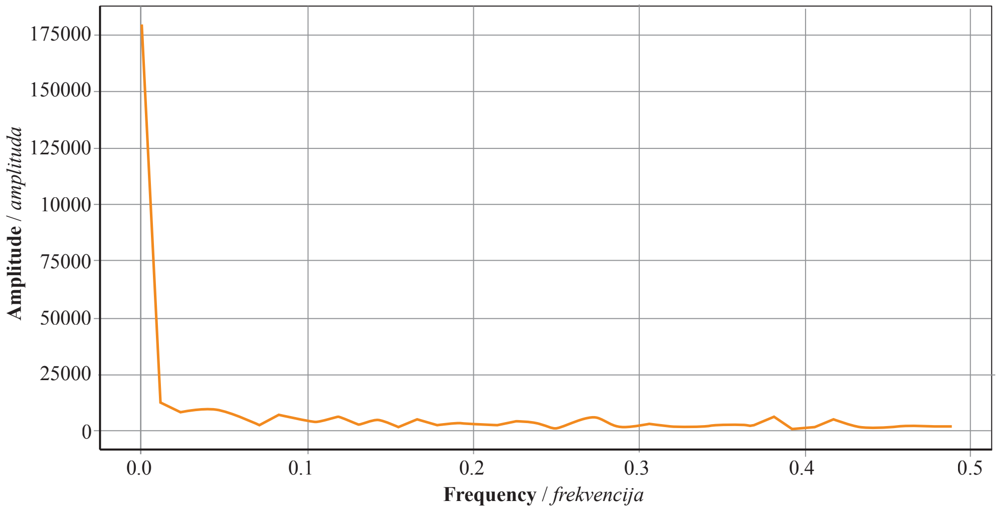

Figure 10 Range of product prices: Round hardwood lumber for sawing and planing (compiled by the authors based on calculations performed)
Slika 10. Raspon cijena za drvo listača za piljenje i blanjanje (sastavili autori na temelju provedenih izračuna)

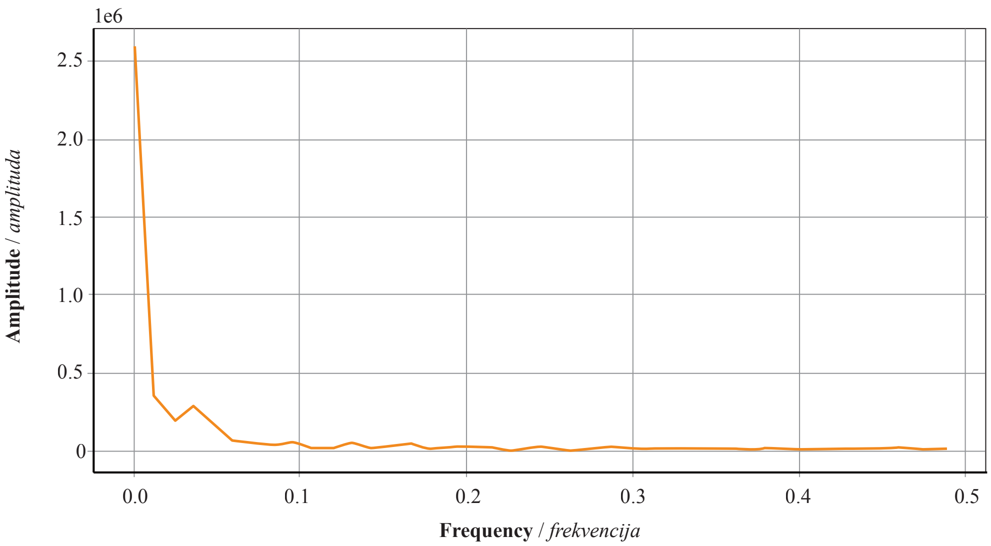

Figure 11 Range of product prices: Plywood (compiled by the authors based on calculations performed)
Slika 11. Raspon cijena za furnirsku ploču (sastavili autori na temelju provedenih izračuna)

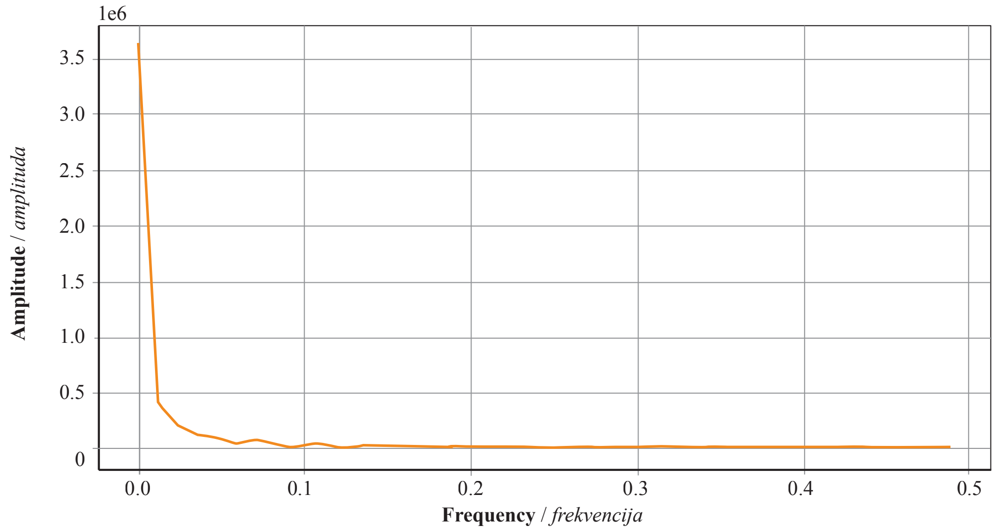

Figure 12 Range of product prices: Wood pulp and cellulose of other fibrous materials (compiled by the authors based on calculations performed)
Slika 12. Raspon cijena za drvnu pulpu i celulozu od ostalih vlaknastih materijala (sastavili autori na temelju provedenih izračuna)

Over the past century, price fluctuations in the forest products market were primarily driven by overarching trends. Seasonal variations exerted a notable influence, while cyclical patterns were less evident and random fluctuations were minimal. The observed patterns of change over time exhibit an increasing prevalence of both ascending, stable, and descending trends. Concurrently, cyclical fluctuations have become more pronounced and impactful. Furthermore, there has been a notable rise in random variation, particularly in recent decades. Future market trends for forestry products will be shaped by the interplay of global supply and demand, technological advancements, and the evolution of environmental regulations. While seasonal price fluctuations may lessen due to international trade expansion and new technologies, cyclical patterns will remain a significant driver of price dynamics. Furthermore, market volatility is expected to rise as a result of increasing complexity and unpredictability in the global economic and political landscape.

Price volatility is analyzed to find out how much the prices of forest products fluctuated from 2017 to 2024 (Table 3).

Based on Table 3, the highest price volatility is observed for corrugated cardboard (standard deviation = 9186.25), while the lowest volatility characterizes pulp and cellulose products (standard deviation = 7.82). The coefficient of variation provides a relative measure, showing that plywood has the highest relative risk (125.2 %) despite lower absolute SD, due to its lower mean price. The line graph illustrated the dynamics of prices for goods with high and low volatility, showing significant fluctuations for «Corrugated cardboard in rolls or sheets» and a much more stable trend for «Wood pulp and cellulose of other fibrous materials» (Figure 13).

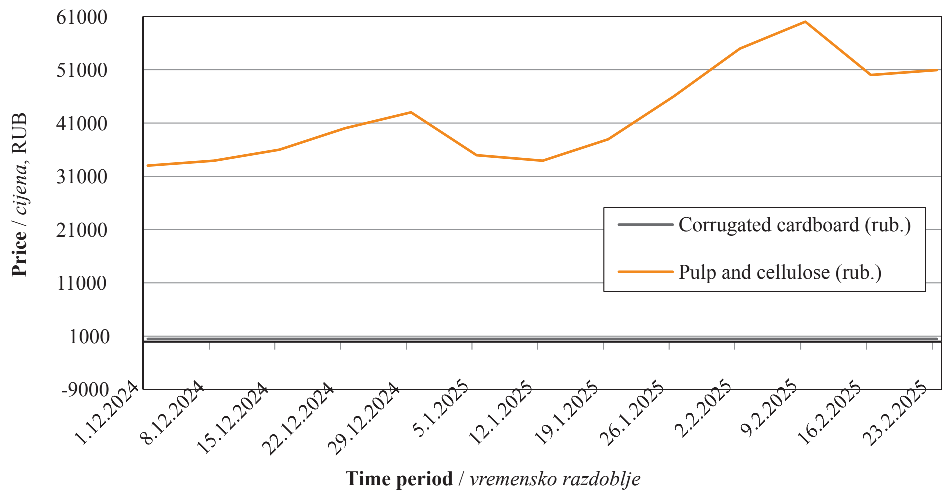

Figure 13 Price dynamics of products with high and low volatility, RUB/ton (corrugated cardboard and pulp and cellulose)
Slika 13. Dinamika cijena proizvoda s visokom i niskom volatilnošću (valovitog kartona i celuloze), RUB/t

When projecting future price trends for forest products, particularly over extended periods, it is essential to consider all relevant factors. This emphasizes the complexity of long-term price forecasting in the forestry sector and highlights the need for a comprehensive approach that accounts for various influential elements.

6 CONCLUSIONS
6. ZAKLJUČAK

Thus, empirical analysis confirmed the high volatility of prices for timber products at the second stage. The volatility observed in current price determination stems from a multifaceted dynamic structure. This structure incorporates not only long-term trends but also recurring seasonal and cyclical patterns, further complicated by unpredictable, random variations. The timber market inherent price fluctuations pose a significant threat to the financial well-being of timber producers. This instability is further compounded by the interconnectedness and predictability of timber prices within Russia, as well as on the global market. Essentially, the text highlights the vulnerability of timber producers to both domestic and international price swings, emphasizing the need for risk management strategies in this volatile industry. The coherence and consistency of the price dynamics of internal and external prices for forest products is confirmed by a high degree of correlation. The future pricing of forest products is projected to remain volatile in both domestic and international markets due to a confluence of intricate factors. The instability inherent in the global and Russian forest products market creates serious economic problems for countries that are heavily dependent on the forest sector. In addition, there are discrepancies between domestic prices for Russian timber products and world prices, primarily due to differences in trade policies of different countries. In this policy, national interests are often put at the forefront by imposing trade barriers such as tariffs, duties and subsidies. Reducing these trade barriers would lead to greater alignment of domestic and international prices. The pricing of timber products in the global market is greatly influenced by the leading exporting and importing countries, which have significant power due to competitive strategies. Large exporters with production advantages can exert downward pressure on prices during periods of weak demand, forcing other participants to adjust their actions accordingly. Ultimately, the balance between supply and demand remains the most important factor determining timber pricing. Therefore, a comprehensive analysis of price levels, trends and relationships between domestic, export and international prices for forest products is crucial for both short-term forecasting and long-term planning in the forest sector.

The practical use of the results of this study opens up prospects for the economy of the forest sector. First of all, the applied analytical framework makes it possible to improve the understanding of price dynamics and enhance the quality of planning and decision-making in the forestry sector, which leads to optimization of production and logistics processes, reduction of risks associated with price fluctuations, and increased profitability of forestry enterprises. Improved forecasting of market conditions allows enterprises to adapt more effectively to changes in demand, reduce costs and increase competitiveness in domestic and foreign markets. In addition, the developed models can be used for the purposes of state regulation of the forestry complex, in particular, to develop measures to support enterprises, stimulate investment and ensure a balanced pricing policy, which will create favorable conditions for the development of the complex.

Based on the results of the project, the scientific team plans to conduct further testing in the activities of business entities of the forest complex, which will allow for the refinement and improvement of the new result. Accurate and timely price forecasting allows companies to make informed decisions in the areas of production planning, raw material procurement, pricing and inventory management. The integration of the developed model into the existing information systems of the enterprise makes it possible to automate the forecasting process and promptly obtain analytical data for making managerial decisions, which reduces dependence on expert assessments, increases the accuracy of forecasts and reduces the risks associated with an incorrect assessment of the market situation. In addition to operational management, the results of the project can be used for long-term strategic planning. Forecasting prices for forest products for several years ahead allows enterprises to assess the profitability of investment projects, develop production development plans and optimize the structure.

Acknowledgements – Zahvala

The research was carried out at the expense of a grant from the Russian Science Foundation (project No. 24-28-01250) on the topic "Development of adaptive models for forecasting prices for forest products".

5 REFERENCES
5. LITERATURA

1. Azarnova, T. V.; Asnina, N. G.; Kolosov, A. I.; Lependin, A. V., 2025: Modifying methodological machine learning approaches for predicting the consumer price index. Urgant, 13 (2): 15-23.
2. Burdakova, G. I.; Byankin, A. S.; Meshkov, A. S., 2023: Research of regional demand for timber industry products under conditions of external sanctions pressures.

π-Economy, 16 (1): 98-113. https://doi.org/10.18721/JE.16107
3. ***Consumer Price Index Manual, 2020: Concepts and Methods. Washington, DC, International Monetary Fund, p. 506., ISBN 978-1-4843-5484-1.
4. Dewhurst, J. F.; Coppock, J. O.; Yates, P. L., 1961: Europe's needs and resources. New York, The Twentieth Century Fund.
5. Dzerjinsky, R. I.; Pronina, E. N.; Dzerzhinskaya, M. R., 2020: Structural analysis of world gold price dynamics. Advances in Intelligent Systems and Computing: 352-365. https://doi.org/10.1007/978-3-030-51971-1_29
6. Jankowska, A.; Zbieć, M.; Kozakiewicz, P.; Koczan, G.; Oleńska, S.; Beer, P., 2018: The wettability and surface free energy of sawn, sliced and sanded European oak wood. Maderas: Ciencia y Tecnología, 20 (3): 443-454. https://doi.org/10.1007/s13213-011-0384-5
7. Kärki, T., 2001: Variation of wood density and shrinkage in European aspen (*Populus tremula*). Holz als Roh- und Werkstoff, 59: 79-84. https://doi.org/10.1007/s001070050479
8. Landsberg, G. G.; Fishman, L. L.; Fisher, J. L., 1965: U.S. resources in the future, vol. 1-2. Washington, DC.
9. McConnell, T. E.; Da Silva, B. K.; Sun, C.; Tanger, S. M., 2021: Forest to mill timber price trends and volatility for Mississippi timber products. Forest Products Journal, 71 (2): 177-187. https://doi.org/10.13073/fpj-d-21-00010
10. Meadows, D. H.; Meadows, D. L.; Randers, J.; Behrens, S., 1991: The limits to growth: The 20-year update. White River Junction, Chelsea Green Publishing.
11. Medvedev, S.; Mokhirev, A.; Rjabova, T., 2022: The added value of products as a key factor in the development of the forest industry. IOP Conference Series: Earth and Environmental Science, 988 (3): 032048. https://doi.org/10.1088/1755-1315/988/3/032048
12. Pyzhyev, A. I., 2024: Elasticity of demand for forest products in the macroregions of Russia: Modeling for forecasting industry development. Terra Economicus, 22 (1): 104-116. https://doi.org/10.18522/2073-6606-2024-22-1-104-116
13. Rjabova, T. G.; Mokhirev, A. P.; Medvedev, S. O.; Lyshko, A. S., 2020: Dynamics and factors of timber value in the forest industry of Russia. Fundamental Research, 4: 94-98. https://doi.org/10.17513/fr.42730
14. Saprykin, K. A., 2023: Price forecasting of oil brands: Comparison of machine learning and statistical approaches. Innovations and Investments, 11: 322-325.
15. Samatova, A. P.; Filimonova, I. V., 2025: Methodological basis for oil price forecasting. Interexpo Geo-Siberia, 2 (2): 54-59. https://doi.org/10.33764/2618-981X-2025-2-2-54-59
16. Shiller, R. J., 2020: Popular economic narratives advancing the longest U.S. expansion 2009 – 2019. Journal of Policy Modeling, 42 (4): 791-798.
17. Starikov, E. N.; Evseeva, M. V.; Naumov, I. V., 2022: Industrial growth and specialisation: The impact of government support tools. Journal of New Economy, 23 (3): 86-108. https://doi.org/10.29141/2658-5081-2022-23-3-5
18. Veretekhina, S. V., 2025: Forecasting average export prices using mathematical analysis. Marketing in Russia and Abroad, 1: 39-43.
19. Yezhkin, V. D.; Radionova, M. V., 2024: Machine learning methods for Bitcoin price forecasting. Actual Issues of Economics, 7: 217-226.
20. ***Consumer Price Index Manual, 2020: Concepts and Methods. Washington, DC, International Monetary Fund, p. 506. ISBN 978-1-4843-5484-1.
21. ***Federal State Statistics Service, 2024: Price statistics [online]. Available at: https://rosstat.gov.ru/statistics/price (Accessed: Nov. 2024).
22. ***Finnish birch plywood, 2018: Metsä Wood [online]. Available at: https://www.metsawood.com (Accessed: Jan. 25, 2026).
23. ***Forest Products Annual Market Review 2023 – 2024: [online]. FAO. Available at: https://openknowledge.fao.org/items/0966581f-f8ad-42bd-a69c-8ffcd9ee325d (Accessed: Jan. 25, 2026).
24. ***Forest Products Annual Market Review 2023 – 2024: [online]. UNECE. Available at: https://unece.org/forests/publications/forest-products-annual-market-review-2023-2024 (Accessed: Jan. 25, 2026).
25. ***Global Forest Products Prices & Market Analysis [online]. Fastmarkets. Available at: https://www.fastmarkets.com/forest-products/ (Accessed: Jan. 25, 2026).
26. ***The global tropical timber market is experiencing a new dawn: the stabilization of supplies in Africa signals the recovery of trade [online]. SHD Wood. Available at: https://www.shdtimber.com/ru/global-tropical-timber-market-sees-new-dawn-african-supply-stabilizes-signaling-trade-recovery.html (Accessed: Jan. 25, 2026).

Corresponding address:

OLGA SUSHKO

Russian University of Economics named after G.V. Plekhanov, MGTU GA, Moscow, RUSSIA,
e-mail: Sushko.OP@rea.ru