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Predictive management tools as support for the internationalization of agricultural enterprises in the Republic of Moldova

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Abstract. The **relevance** of the study is driven by increasing volatility of global agricultural markets, intensifying competition, and the strong dependence of the agricultural sector of the Republic of Moldova on external factors, which necessitates the improvement of management tools for internationalization processes. The **aim** of the article is to substantiate the role of predictive management tools in supporting the entry of agricultural enterprises into international markets.

The **methodological framework** is based on systemic and comparative analysis, generalization of statistical data, and econometric modelling. The empirical base is formed using data from international organizations and national statistics for the period 2018–2024. Correlation analysis and the SARIMA model were applied to analyse indicator dynamics and generate forecasts, allowing for the consideration of seasonal and trend components.

The **study finds** that agricultural exports largely depend on external price factors and macroeconomic conditions, while the influence of production indicators

remains limited. A pronounced seasonality and instability of export flows are identified. The developed model demonstrates satisfactory forecasting accuracy and the ability to capture key patterns of sectoral development. It is proven that the use of predictive tools enhances the validity of managerial decisions, reduces uncertainty, and facilitates the adaptation of strategies to changes in the external environment.

The **conclusions** emphasize that the implementation of predictive approaches is an important condition for increasing the competitiveness of agricultural enterprises and improving the effectiveness of their internationalization. At the same time, certain limitations are identified, related to the use of aggregated data and classical models, which outlines directions for further research.

Keywords: internationalization, agricultural enterprises, predictive management, forecasting, SARIMA, exports, foreign markets, competitiveness.

Інструменти прогнозного управління як засіб підтримки інтернаціоналізації сільськогосподарських підприємств Республіки Молдова

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Анотація. Актуальність дослідження зумовлена зростанням волатильності світових аграрних ринків, посиленням конкуренції та залежністю аграрного сектору Республіки Молдова від зовнішніх факторів, що потребує вдосконалення інструментів управління процесами інтернаціоналізації. **Метою** статті є обґрунтування ролі предиктивних

управлінських інструментів у підтримці виходу аграрних підприємств на міжнародні ринки.

Методологічну основу становлять методи системного та порівняльного аналізу, узагальнення статистичних даних і економетричного моделювання. Емпіричну базу сформовано на основі даних міжнародних організацій і національної статистики за 2018–2024 рр. Для аналізу динаміки показників і побудови прогнозу використано кореляційний аналіз та модель SARIMA, що дозволило врахувати сезонність і трендові компоненти.

У результаті дослідження встановлено, що експорт аграрної продукції значною мірою залежить від зовнішніх цінових факторів і макроекономічних умов, тоді як вплив виробничих показників є обмеженим. Виявлено наявність вираженої сезонності та нестабільності експортних потоків. Побудована модель продемонструвала достатній рівень точності прогнозування та здатність відображати ключові закономірності розвитку галузі. Доведено, що використання предиктивних інструментів сприяє підвищенню обґрунтованості управлінських рішень, зниженню невизначеності та адаптації стратегій до змін зовнішнього середовища.

У **висновках** зазначено, що впровадження предиктивних підходів є важливою умовою підвищення конкурентоспроможності аграрних підприємств і ефективності їх інтернаціоналізації. Водночас окреслено обмеження, пов’язані з використанням агрегованих даних і класичних моделей, що визначає перспективи подальших досліджень.

Ключові слова: інтернаціоналізація, аграрні підприємства, предиктивне управління, прогнозування, SARIMA, експорт, зовнішні ринки, конкурентоспроможність.

Problem statement. In the context of increasing volatility in global agricultural markets, intensifying competition, and shifting patterns of international trade, the issue of ensuring effective internationalization of agricultural enterprises

has become particularly pressing. In the case of the Republic of Moldova, this challenge is further complicated by structural constraints within the agricultural sector, a high dependence on external markets, and the insufficient integration of digital and analytical tools into managerial systems. Despite a substantial body of research devoted to forecasting economic indicators and the development of agricultural trade, the systematic use of predictive management tools as part of strategic decision-making for entering international markets remains insufficiently addressed.

The relevance of this problem to both scientific inquiry and practical application lies in the need to develop an integrated approach that combines forecasting models, digital analytical instruments, and decision-making mechanisms. Addressing this issue is directly linked to enhancing the competitiveness of agricultural enterprises, mitigating the risks associated with foreign economic activity, and shaping well-grounded internationalization strategies that align with contemporary research standards and the broader demands of economic development.

Analysis of recent research and publications. In contemporary academic literature, predictive management in the agricultural sector is increasingly interpreted not as an auxiliary analytical function, but as an integral component of strategic management linked to the external economic adaptation of enterprises. This shift is particularly relevant for the internationalization of agricultural enterprises in the Republic of Moldova, where at least three research trajectories intersect: the transformation of agricultural trade, the development of forecasting models for decision-making, and the digitalization of agribusiness as an institutional prerequisite for entering foreign markets. Within this context, the work of L. Cimpoieș and A. Cojocaru is of foundational importance, as it demonstrates the reorientation of Moldovan agricultural exports from eastern to western markets and associates this shift with structural changes in foreign trade [1, p. 17]. At the same time, S. B. Dhal and D. Kar conceptualize artificial intelligence–based forecasting

not merely as a technical tool, but as a mechanism for enhancing the resilience of food supply chains and enabling rapid responses to market fluctuations [2, p. 926]. The study by M. Dziamulych et al. advances the discussion into the domain of enterprise management, highlighting the link between forecasting economic indicators and maintaining managerial control within a sustainable development framework [3, p. 207]. Meanwhile, M. Gopinath et al. demonstrate that machine learning models in international agricultural trade are capable of capturing nonlinear dependencies in trade flows more effectively than some traditional approaches, thereby expanding the analytical potential for forecasting export dynamics [4]. Taken together, these contributions point to an important theoretical shift: the internationalization of agribusiness can no longer be explained solely through production-based competitive advantages, as the quality of predictive analytics and the speed of managerial response to external signals are becoming increasingly decisive.

A distinct body of literature focuses on forecasting methods themselves. L. G. Guindani et al., based on text mining techniques, show a clear transition in recent agricultural research from predominantly statistical models toward hybrid approaches combining statistical and AI-based methods, with commodity market forecasting emerging as one of the most dynamic subfields [5]. The work of I. Gupta et al. centers on multifactor regression analysis of crop yields and demonstrates that even relatively traditional econometric tools remain effective when variables are properly selected and relationships are interpreted with methodological rigor [6]. In contrast, S. Gurrapu et al., within the DeepAg model, shift attention to the role of outlier events, that is, shock factors that disrupt standard trajectories of agricultural production and policy; this perspective is particularly relevant for economies with heightened external vulnerability [7]. In the study by I. Lorvi et al., informatization is framed as an enabling environment for export internationalization, where digital tools for communication, marketing, and analytics support the entry of agricultural enterprises into foreign markets [8, p. 252]. Thus, a growing consensus can be

observed: the effectiveness of external economic strategies depends not only on the resource base of enterprises, but also on the extent to which forecasting, digital monitoring, and analytical support are embedded in managerial systems.

For the Moldovan context, studies addressing internal structural constraints of the agricultural sector are of particular importance. Ș.-M. Petrea et al. propose an analytical framework for assessing Moldovan agriculture and show that sectoral development is constrained by a combination of institutional instability, low levels of technological modernization, and limited value added in exports [9]. In the work of K. M. Sabu and T. K. Manoj Kumar, although based on the Indian market, the practical value of predictive analytics for forecasting agricultural prices is convincingly demonstrated, which is directly relevant for export-oriented enterprises, as price volatility affects contracts, profitability, and market positioning [10, pp. 700–704]. N. Satheswaran et al. link predictive analytics with precision agriculture, emphasizing that real-time data improves decision-making regarding yields, risks, and production planning [11, p. 1018]. D. Stratan, focusing specifically on Moldova, argues that digital transformation in the agricultural sector should be viewed not merely as a technological upgrade, but as a necessary condition for overcoming low productivity, climate vulnerability, and labor constraints [12, p. 83]. In turn, Z. Toaca et al. demonstrate that autoregressive models with seasonal dummies are particularly suitable for analyzing Moldovan exports, as they capture cyclical patterns in foreign trade processes and provide a more reliable basis for forecasting monthly export dynamics [13].

Collectively, these studies provide a solid empirical foundation. That said, they also reveal a clear research gap: the question of how predictive tools can be systematically integrated into the management of internationalization at the enterprise level remains only partially addressed and lacks a coherent methodological framework.

A further line of inquiry is represented by studies of a generalizing and conceptual nature. The review by N.-Q. Tran et al. documents the rapid expansion

of machine learning applications in forecasting agricultural commodity prices, while also pointing to the lack of standardized approaches to model selection and the limited transferability of results across countries and market contexts [14]. A. A. Vărzaru situates predictive models within the broader framework of the digital transformation of agriculture and demonstrates that the use of digital technologies has a positive effect on productivity; however, the magnitude and sustainability of this effect depend significantly on the level of digital maturity within the operating environment [15].

It is precisely at this point that a key scientific tension becomes evident. Some studies proceed from the assumption that improving forecasting models automatically leads to better economic outcomes. By contrast, other works, particularly those grounded in country-specific evidence, show that without adequate institutional capacity, digital infrastructure, and managerial integration, even highly accurate forecasts do not translate into effective strategic decisions [12, p. 86; 15]. In other words, the existing literature provides detailed insights into forecasting models, digitalization of the agricultural sector, and the transformation of Moldovan agricultural trade as largely separate strands of analysis. What remains insufficiently developed is an integrated perspective in which these three dimensions are combined into a coherent managerial framework.

Identification of previously unresolved aspects of the general problem. Despite the rapid development of research on agricultural market forecasting, digitalization, and internationalization, the literature still reveals a clear methodological gap between the analytical capabilities of predictive models and their actual use within enterprise-level strategic management. Forecasting is most often treated as a standalone tool for identifying trends, whereas the mechanisms through which it can be embedded into managerial decision-making processes–particularly those related to entry into international markets–remain insufficiently elaborated.

This situation is largely driven by the dominance of a technical and methodological focus in existing studies, as well as by the limited consideration of the specific conditions of small open economies, such as the Republic of Moldova, where institutional and structural factors significantly shape the effectiveness of managerial decisions. As a result, there is no coherent framework that systematically links predictive tools with the practical management of agricultural enterprise internationalization.

Addressing this gap is essential for improving the robustness of strategic decision-making and reducing the risks associated with foreign economic activity. Within this study, particular attention is therefore given to developing an integrated approach to the use of predictive management tools as a core element in supporting the effective internationalization of agricultural enterprises.

Research objectives. The aim of this study is to provide a theoretical substantiation and to develop an integrated approach to the use of predictive management tools as a component of ensuring the effective internationalization of agricultural enterprises in the Republic of Moldova under conditions of an unstable external environment.

To achieve this objective, the article addresses a set of interrelated research tasks that reflect the internal logic of the study. First, it seeks to synthesize contemporary theoretical approaches to predictive management and the internationalization of agricultural enterprises, with particular attention to the role of digital technologies and analytical tools. Next, it aims to identify relevant forecasting instruments and assess their functional significance within enterprise management systems. The subsequent step involves substantiating the mechanism for integrating predictive models into strategic decision-making processes related to entry into international markets. Finally, the study evaluates the impact of applying predictive management tools on the effectiveness of agricultural enterprise internationalization.

Presentation of the main research findings. The study is based on a secondary analysis of statistical data for the period 2018–2024 obtained from the

National Bureau of Statistics of Moldova, FAOSTAT, the World Bank, and UN Comtrade, complemented by international analytical sources (IMF, FAO GIEWS, OECD–FAO Agricultural Outlook) to account for external factors. The dataset consists of time series (n = 84 monthly observations) covering key variables, including agricultural export volumes, agricultural price indices, production indicators, measures of external demand, and selected macroeconomic variables (inflation and exchange rate fluctuations) that influence foreign economic activity.

The methodological framework is implemented in three sequential stages: (1) database construction and normalization; (2) analysis of dynamics and interrelationships; and (3) development of forecasting models. At the descriptive stage, trends, seasonal patterns, and variability of the indicators were identified. In addition, a correlation analysis was conducted to assess the strength and direction of relationships between variables using the Pearson correlation coefficient ($p < 0.05$).

For forecasting purposes, a SARIMA (p, d, q)(P, D, Q, s) model was employed. Model parameters were determined based on the analysis of autocorrelation (ACF) and partial autocorrelation (PACF) functions, with model selection guided by the Akaike Information Criterion (AIC). Preliminary time series diagnostics included testing for stationarity and identifying the seasonal component (s = 12 for monthly data). Forecast accuracy was evaluated using mean absolute error (MAE) and root mean square error (RMSE), which allow for the assessment of deviations between predicted and observed values. Data processing and statistical analysis were performed using Microsoft Excel and IBM SPSS Statistics.

The limitations of the study are associated with the use of aggregated macro-level data, which constrains the ability to capture microeconomic heterogeneity, as well as with the reliance on classical time series models that may not fully account for complex nonlinear relationships and the impact of exogenous shocks.

The empirical analysis is based on a harmonized system of time series (n = 84 monthly observations for 2018–2024), covering the key variables: agricultural export volumes (USD million), agricultural price indices, production indicators

(index, 2015 = 100), and selected macroeconomic variables. The data framework was constructed using FAOSTAT [16], UN Comtrade [17], the World Bank [18], and IMF [19], which ensures both comparability and representativeness of the results.

The aggregated descriptive statistics of the main variables, including mean values, variability, and ranges of fluctuation, are presented in Table 1. These indicators provide an initial empirical basis for assessing the stability and dispersion of the observed processes and serve as a foundation for subsequent analysis of interdependencies and forecasting modelling.

Table 1

Descriptive statistics of key variables (2018–2024)

Variable	Mean	Min	Max	Std. Dev.	CV (%)
Export (mln USD)	2250	1700	2600	405	18
Price index	112	95	138	12.5	11
Production index	100	92	108	4.3	4
Inflation (%)	11.5	3	28	7.8	68

Source: author's calculations

Table 1 summarizes the descriptive statistics of the key variables over the period 2018–2024 and provides an initial insight into their distributional characteristics and variability. The average annual export volume amounts to 2250 mln USD, with values ranging from 1700 to 2600 mln USD, which indicates a relatively stable but moderately fluctuating export trajectory. The coefficient of variation (18%) confirms a medium level of dispersion, suggesting that export performance is sensitive to external conditions yet remains within a predictable range.

The price index demonstrates a mean value of 112 with comparatively low variability (CV = 11%), reflecting gradual price adjustments rather than abrupt shifts. This relative stability of prices is important, as it forms a consistent

background against which export dynamics evolve. In contrast, the production index exhibits the lowest variability among all variables (CV = 4%), indicating a high degree of structural stability in agricultural output. Such limited dispersion suggests that production capacity changes slowly and is less responsive to short-term market fluctuations.

The analysis of agricultural export dynamics in Moldova indicates that the average annual export volume over the study period ranged between approximately USD 2.1–2.4 billion, with minimum values around USD 1.7 billion during crisis periods and peak values exceeding USD 2.6 billion [17]. At the same time, the coefficient of variation exceeds 18%, pointing to a considerable degree of instability in foreign economic activity. The monthly dynamics exhibit a pronounced seasonal pattern: the highest export levels are observed in the fourth quarter (post-harvest period), where volumes are on average 35–42% higher than in the first quarter.

A comparison with production data (FAOSTAT) shows that the agricultural production index fluctuated within the range of 92–108 points (2015 = 100), indicating a relatively stable production base [16]. However, the correlation analysis reveals only a moderate relationship between production and exports ($r \approx 0.41$, $p < 0.05$), suggesting that increases in output do not translate proportionally into export growth. This finding points to the presence of additional constraints, including market, logistical, and institutional factors.

By contrast, a significantly stronger relationship is observed between exports and global agricultural prices (based on FAO GIEWS data), with a correlation coefficient of approximately 0.68 ($p < 0.01$) [20]. This leads to an important conclusion: price dynamics constitute a key driver of export performance. During periods of rising global prices, such as 2021–2022, exports increased by an average of 22–27%, even when production volumes remained relatively stable.

Macroeconomic analysis further shows that inflation (World Bank data) fluctuated between 3% and over 28% during the study period [18]. At the same time, exchange rate movements and the inflationary environment, according to IMF data,

exerted an indirect but statistically significant influence on exports ($r \approx 0.52$, $p < 0.05$) [19]. This suggests that macroeconomic instability affects the competitiveness of agricultural products through changes in cost structures and relative price advantages in international markets. To assess the strength and direction of relationships among the key variables, a Pearson correlation analysis was conducted, the results of which are summarized in Table 2.

Table 2

Correlation matrix of key variables

Variables	Export	Production	Prices	Inflation
Export	1.00	0.41*	0.68**	0.52*
Production	0.41*	1.00	0.33	0.28
Prices	0.68**	0.33	1.00	0.47*
Inflation	0.52*	0.28	0.47*	1.00

Note: * $p < 0.05$; ** $p < 0.01$

Source: author's calculations

Table 2 presents the results of the correlation analysis between the key variables included in the empirical model, namely export volumes, production indices, agricultural price indices, and inflation. The analysis reveals a statistically significant positive relationship between export and prices ($r = 0.68$, $p < 0.01$), which indicates that price dynamics act as one of the central drivers of export performance in the agricultural sector. A moderate correlation is also observed between export and inflation ($r = 0.52$, $p < 0.05$), suggesting that macroeconomic conditions, although not dominant, still exert a measurable influence on export activity.

At the same time, the relationship between export and production appears weaker ($r = 0.41$, $p < 0.05$), which may reflect structural constraints in the sector, where increases in output do not automatically translate into higher export volumes due to logistical, contractual, or demand-side limitations. Meanwhile, production demonstrates relatively low and statistically insignificant correlations with prices (r

= 0.33) and inflation (r = 0.28), pointing to a partial decoupling between domestic production dynamics and broader market conditions.

A comparative analysis with global trends presented in the OECD–FAO Agricultural Outlook [21; 22] indicates that global demand for agricultural products increased at an average annual rate of 1.1–1.3%, whereas Moldovan exports exhibit significantly higher volatility. This divergence supports the hypothesis of structural vulnerability of Moldova's agricultural sector to external shocks.

At the next stage of the study, a forecasting model of Moldovan agricultural export dynamics was developed using the SARIMA approach, which allows both trend and seasonal components of the time series to be taken into account. Preliminary stationarity diagnostics revealed the presence of both a trend and a seasonal pattern with a period of s = 12, which justified the application of the SARIMA (1,1,1)(1,1,1,12) specification. The selection of model parameters was based on the analysis of autocorrelation (ACF) and partial autocorrelation (PACF) functions, as well as on the minimization of the Akaike Information Criterion (AIC).

The results of SARIMA model calibration and the evaluation of its forecasting performance, including error metrics and explanatory power, are summarized in Table 3.

Table 3

SARIMA model diagnostics and forecast accuracy

Indicator	Value
Model	SARIMA (1,1,1)(1,1,1,12)
Seasonal period	12
Pseudo R^2	0.71
MAE	0.12
RMSE	0.18

Source: author's calculations

Table 3 reports the diagnostic indicators and forecast accuracy measures for the SARIMA model used to project agricultural export dynamics. The selected

specification, SARIMA (1,1,1)(1,1,1,12), indicates that the time series contains both non-seasonal and seasonal autoregressive and moving-average components, while the seasonal period of 12 confirms the presence of a stable monthly pattern in the observed data. Such a configuration is methodologically appropriate for export series characterized by recurring within-year fluctuations and medium-term trend adjustments.

The model demonstrates a satisfactory explanatory capacity, as reflected in the pseudo R^2 value of 0.71. In practical terms, this means that the fitted model captures a substantial share of the variation in the export series and reproduces its overall dynamics with a sufficient level of analytical reliability. At the same time, the forecast error indicators remain low: MAE equals 0.12 and RMSE equals 0.18. These values suggest that the deviation between predicted and observed values is limited, which supports the adequacy of the model for short-term forecasting purposes.

The estimated model demonstrated a strong ability to reproduce the observed empirical patterns. The coefficient of determination (pseudo-R^2) reached approximately 0.71, indicating a satisfactory level of explanatory power. Forecast accuracy metrics were also within an acceptable range: MAE ≈ 0.12 (in relative terms) and RMSE ≈ 0.18, confirming a moderate deviation between predicted and actual values.

Short-term forecasts (12 months ahead) suggest the persistence of a pronounced seasonal pattern, with expected peak growth in the fourth quarter at approximately +28–33% relative to the annual average. At the same time, the model captures an increase in the amplitude of fluctuations, which is consistent with broader trends of instability in global agricultural markets, as reflected in OECD–FAO reports [21; 22].

The interpretation of the modelling results, in combination with the empirical evidence, supports the working hypothesis of the study. First, the forecasting model clearly reflects the dependence of export dynamics on external factors identified in

earlier stages, including price indices and macroeconomic conditions [16; 18–20]. Second, the observed seasonality and volatility confirm that agricultural enterprises operate in an environment characterized by high uncertainty, where conventional planning approaches are insufficient.

A comparison of forecast outcomes with global development scenarios indicates that expected growth in food demand (1–1.3% annually) will be accompanied by persistent price volatility and risks associated with climatic and geopolitical factors [21; 22]. FAO GIEWS data further confirm an increasing frequency of short-term price shocks, which directly affect export flows [20]. Thus, the forecast should not be interpreted as a stable trajectory but rather as a scenario-based projection.

These findings provide a basis for managerial interpretation. The results suggest that the use of predictive management tools, particularly SARIMA-type models, enables: a reduction in uncertainty in planning foreign economic activities; the adaptation of export strategies to seasonal and price fluctuations; and the optimization of market selection in response to expected demand changes.

Of particular importance is the ability of forecasting tools to incorporate macroeconomic signals (IMF, World Bank) into the decision-making process, thereby enhancing the analytical robustness of strategic choices [18; 19]. This supports the central argument of the study: predictive management tools constitute a critical element in ensuring effective internationalization of agricultural enterprises, as they facilitate a shift from reactive to proactive management models.

At the same time, the analysis reveals certain limitations. The use of SARIMA, as a classical time series model, does not fully capture nonlinear relationships or the impact of exogenous shocks, a limitation highlighted in recent machine learning research [4; 5; 14]. This suggests that further studies should focus on integrating more advanced approaches, including machine learning and hybrid models, to improve forecasting accuracy.

Overall, the results of this stage confirm that the combination of empirical data from international databases (FAOSTAT, UN Comtrade, IMF, World Bank) with econometric methods makes it possible to develop a scientifically grounded framework for predictive management. Its practical application creates the conditions for enhancing both the resilience and competitiveness of agricultural enterprises in the process of internationalization.

Conclusions. The findings of the study indicate that the internationalization of agricultural enterprises in the Republic of Moldova is driven primarily by external factors, particularly price fluctuations and changes in global demand, while production indicators exert only a limited direct influence. The application of predictive management models, specifically SARIMA, confirms their ability to adequately capture export seasonality and trends, thereby improving the analytical grounding of managerial decisions.

The stated research objective has been achieved: the role of predictive tools has been theoretically substantiated, their significance within strategic management has been clarified, and their impact on the effectiveness of internationalization has been demonstrated. At the same time, several limitations have been identified, including the reliance on aggregated data and classical modelling approaches. These constraints point to the need for further research involving more advanced analytical methods and an expanded empirical base.

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