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ADAPTATION OF STATISTICAL CRITERIA TO CURRENCY RISK MANAGEMENT IN THE CONTEXT OF GLOBAL UNCERTAINTY

АДАПТАЦІЯ СТАТИСТИЧНИХ КРИТЕРІЇВ ДО УПРАВЛІННЯ ВАЛЮТНИМИ РИЗИКАМИ В УМОВАХ ГЛОБАЛЬНОЇ НЕВИЗНАЧЕНОСТІ

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Abstract. The article presents the results of the analysis of the study of the possibilities of using statistical quality criteria to assess and manage currency risk in the context of global uncertainty caused by currency market fluctuations. It describes the applicability of the mathematical apparatus of statistical criteria for assessing management to the analysis of currency risks. The analysis is based on the methods of comparing the existing practice of responding to manifestations of currency market fluctuations, their protective and preventive measures in order to minimize losses when performing currency transactions, contractual obligations and financial settlements with the formalization of the essence of statistical quality criteria, recommendations and application possibilities. Based on the possible manifestations of specific statistical criteria in various situations of currency risk management during currency market fluctuations, a conclusion is made on the possibility of using statistical quality criteria in managing currency markets under uncertainty. Recommendations are provided for the implementation of specific statistical criteria. Using currency risk management solutions, companies can present their currency positions, ensuring accurate data processing and quickly respond to changes in the currency market, increasing the overall effectiveness of management. An illustration of the results of comparisons of existing criteria under uncertainty and statistical criteria for assessing currency risk is the systematization of their possible manifestations in currency risk management technologies in the form of insurance options, hedging instruments, currency clauses, mortgages, and fixed-rate contracts. The scientific novelty of the

proposed direction of regulation and management of currency risk is the operations performed in this case related to assessing the situation, identifying markets, assessing additional costs for protecting participants, insuring deposits, deposits, and customer accounts. Practical significance is achieved by applying transactions using certain financial instruments to compensate for the possible negative effect of an impending currency crisis.
Key words: currency market; financial instruments; statistical criteria; companies.

Анотація. Наводяться результати аналізу вивчення можливостей використання статистичних критеріїв якості для оцінки та управління валютним ризиком за умов глобальної невизначеності, викликаної коливаннями ринку валют. Дається опис застосування математичного апарату статистичних критеріальних оцінок управління до аналізу валютних ризиків. В основу аналізу покладено методики порівняння існуючої практики реагування на прояви коливань ринку валют, їх захисні та запобіжні заходи з метою мінімізації втрат при виконанні валютних операцій, договірних зобов'язань та фінансових розрахунків із формалізацією сутності статистичних критеріїв якості, рекомендаціями та можливостями застосування. З можливих проявів конкретних статистичних критеріїв у різних ситуаціях управління валютним ризиком при коливаннях валютних ринків зроблено висновок можливість використання статистичних критеріїв якості під час управління валютними ринками за умов невизначеності. Наводяться рекомендації щодо впровадження конкретних статистичних критеріїв. Використовуючи рішення щодо управління валютним ризиком, компанії можуть подати свої валютні позиції, забезпечивши точну обробку даних та швидко реагувати на зміни валютного ринку, підвищуючи загальну ефективність правління. Ілюстрацією результатів порівнянь існуючих критеріїв за умов невизначеності та статистичних критеріїв оцінки валютного ризику є систематизація їх можливих проявів у технологіях управління валютними ризиками як варіантів страхування, інструментів хеджування, валютних застережень, іпотек, договорів із фіксованим курсом. Науковою новизною запропонованого напряму регулювання та управління валютним ризиком є операції, пов'язані з оцінкою ситуації, ідентифікацією ринків, оцінкою додаткових витрат на захист учасників, страхуванням вкладів, депозитів і рахунків клієнтів. Практична значущість досягається застосуванням угод з використанням певних фінансових інструментів для компенсації можливого негативного ефекту від валютної кризи, що насувається.
Ключові слова: валютний ринок; фінансові інструменти; статистичні критерії; компанії.

STATEMENT OF THE PROBLEM

Foreign exchange risk management is critical for companies engaged in international operations to maintain financial stability by avoiding financial stress from adverse exchange rate fluctuations, protecting against the financial impact of geopolitical events and economic crises. By effectively managing foreign exchange funds, companies can protect the value of their assets and liabilities denominated in foreign currencies, securing their balance sheets.

Improving the decision-making process can be achieved by using modeling of foreign exchange risk management processes and statistical criteria for assessing changes in exchange rates, allowing us to consider various options for making decisions to eliminate or reduce foreign exchange risk. Evaluation of foreign exchange market fluctuations is based on modeling and forecasting exchange rate dynamics, key trends and tendencies, information security and access to market information. The complexity of managing and forecasting foreign exchange risks increases due to globalization and liberalization of financial relations between countries.

Uncertainty and unpredictability of expected crisis changes caused by instability of international relations and imbalance of foreign economic relations in the conditions of globalization of financial markets, forces to look for new more progressive methods of regulation and prevention of currency risk in order to avoid possible financial losses and damages. Global economic changes are not subject to strictly established patterns and trends, but rather relate to random probabilistic processes with their own criteria for the quality of assessment of the current and predicted situation. The existence of objective uncertainty determines the probabilistic nature of the criteria for managing currency risks. Taking into account probabilistic ideas, the currency risk of damage from exchange rate fluctuations when making management decisions inadequate to impending events will depend on statistical realizations of random processes. Accordingly, the assessment of the decision taken to regulate and prevent fluctuations in the currency market will be combined into one more or less plausible result, which combines a set of probabilities of damage and profit. Such implementation of difficult to formalize currency risk management tasks can be accomplished by constructing expert systems using appropriate criteria.

The process of currency risk management is especially relevant due to the volatility of exchange rates, which necessitates the improvement of existing and the search for fundamentally new methods of criteria and tools for modeling currency risk management.

ANALYSIS OF REMAINING RESEARCH AND PUBLICATIONS

Analysis of publications on the problem of currency risk management shows significant interest in forecasting the foreign exchange market, which is a hot topic among

economists, traders, participants and researchers of the foreign exchange market. Modeling the interdependence and risk of portfolio value with price series using the autoregressive valuation model in volatile periods is performed in [1]. The advantages of probabilistic forecasts for a number of financial assets are shown. Dynamic correlations of currency-price management factors and their joint distribution are studied in [2]. To improve the model for forecasting the exchange rate, statistical control methods are used in [3]. Conclusions are made that floating exchange rates are better approximated as random walk processes using machine learning of existing models and selector maps [4]. Emphasis is placed on the prospects of statistical methods for studying currency risks [5]. Multifractality of statistical measurements of time series of exchange rates with individual and cross correlations for understanding the nature of price movements and exchange rate dynamics is described in [6]. In [7], exchange rate fluctuations that create uncertainty in the currency markets are studied. The risk of the currency transaction portfolio is measured based on the Monte Carlo model. However, its practical implementation is associated with significant difficulties associated with the complexity of modeling joint multidimensional asset distributions in the portfolio.

Models of dispersion and covariance of asset returns in risk management are presented in [8]. The models were tested for a data set of five exchange-traded funds and five currencies. A similar practice of determining the stability of profitability and price volatility in the markets is described in [9]. The optimal combination of a model for managing operational currency and credit risks when determining bank development strategies is described in [10].

The results of works [11–13] can serve as support for statistical methods of assessing currency risks under uncertainty. To synthesize the data, the construction of a currency portfolio with various international underlying assets was studied based on big data analysis and probabilistic statistical models. Machine learning models with major world indices are used to predict the expected return and their volatility for preprocessing. After that, the income is predicted to form a portfolio with average variance. The use of business analytics based on a deep neural network in assessing credit risk at a controlled level is described in [14, 15], a comparative analysis of the probability of currency volatility clusters is presented in [16], currency hedging for a multinational company is described in [17], the role of financial risks in megatransport projects in developing countries is described in [18]. It is concluded that despite key innovations including big data analytics, artificial intelligence, digital currency, blockchain, the Internet of things, opening up new horizons, changing the behavior of customers in the banking industry, banking risk management is the weakest link in the financial regulation of banks in the chain of representations of rapid global unpredictable changes.

Analysis of existing statistical criteria for the quality of probabilistic processes of expectation of crisis changes in the exchange rate, the development of mathematical models for managing financial instruments and strategies for their behavior is a poorly studied problem of economic and mathematical modeling and its practical applications.

SEPARATION OF PREVIOUSLY UNSOLVED PARTS OF THE GENERAL PROBLEM

Unresolved parts of the general problem of managing currency risks in crisis situations include the adaptation of statistical criteria to managing currency risks in conditions of global uncertainty.

PURPOSE OF THE RESEARCH

The purpose of the work is to describe statistical criteria and the possibility of their implementation for their management of currency risks in the conditions of global uncertainty.

Achieving the goal required the implementation of the following tasks:

– description of the information essence of statistical criteria for the quality of assessments of the occurrence of probabilistic situations in conditions of risk uncertainty,

– analysis of their applicability to currency risk assessments in conditions of global instability,

– development of manifestations and recommendations for the use of statistical criteria in the practice of the banking sector of financial risk management.

METHODS, OBJECT AND SUBJECT OF RESEARCH

To achieve this goal, when describing statistical quality criteria, methods of probability theory, statistical and dispersion analysis, time series forecasting, and pattern recognition were used.

Object of research: decision-making processes for managing the development of situations using financial instruments of the banking sector.

Subject of research: statistical criteria of quality and assessment of their application in managing currency risks in conditions of crisis situations.

BASIC MATERIAL

The effectiveness of currency risk management in conditions of uncertainty largely depends on the quality and appropriateness of the application of the necessary criteria, the management schemes used, the accumulation of risk information, the development, as well as the synchronization of financial transactions that accompany the functioning of the banking sector. The statistical method for assessing the quality of decision-making involves the use of typical distribution functions: normal, exponential, and others to assess possible costs, subject to the availability of statistical information. Statistical quality criteria can be used to compare the effectiveness of various methods for assessing and regulating currency risks based on statistical parameters and methods for processing probabilistic information (Fig. 1).

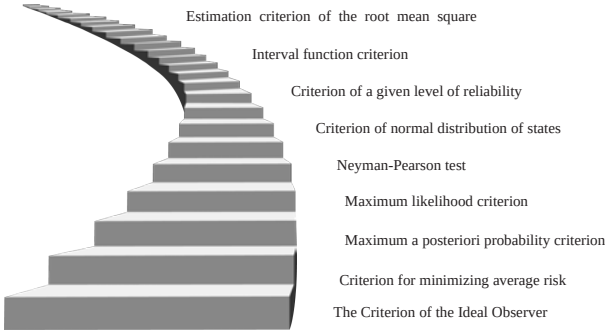

Fig. 1. Criteria of statistical decisions

The consequences of exchange rate fluctuations are different, therefore the criteria for assessing the currency risk are different. Statistical quality criteria are associated with interdependent estimates and probabilistic manifestations of the quality of a priori information and forecasting in the short term. Their application to solving problems of regulation and management under uncertainty is determined by the specification of the tasks to be solved and the intended goals. In their structure, the criteria are not mutually exclusive, but rather complement each other, therefore it is advisable to consider the essence, content and areas of possible adaptation of statistical criteria to assessing exchange rate fluctuations.

The criterion of an ideal observer is used to consider a situation where there is no data on the establishment of losses. It is used to minimize the total probability of errors in making management decisions. It is assumed that the space of realizations of exchange rate fluctuations is finite-dimensional and the result that has the highest a posteriori probability is used. The total probability of error in assessing the consequences of a crisis situation is defined as the mathematical expectation of successive realizations of exchange rate fluctuations.

$$P_{ou} = M\left[P_{ou}(S_i)\right] = \sum^{m} P(S_i)P_{ou}(S_i) \to \min$$

where M – mathematical expectation;

$P_{ou}(S_i)$ – the probability of incorrect assessments of the situation;

m – total number of implementations;

$P(S_i)$ – probability of a crisis situation;

S_i – the total number of exchange rate fluctuations.

The ideal observer criterion ensures the maximum probability of a correct adequate decision in a crisis situation. It manifests itself as a neutral attitude to the problem that has arisen. Recommendations for use consist of small volumes of transactions with equal amounts of profit and loss. The practical actions of the bank consist of limiting the number of currency transactions. Opening of currency accounts by bank clients is not limited by their size, but cash withdrawals are made for a limited amount.

The criterion for minimizing the average risk is introduced in order to take into account the inequality of errors in decision-making. The decision scheme that ensures the lowest value of the average risk is considered optimal. The average risk is called the mathematical expectation of losses associated with the decision being made. The criterion for the minimum average risk takes into account the consequences of making decisions that are adequate to the current situation.

Having designated through P_k the probability of mispricing exchange rate fluctuations S_k and through L_k the amount of damage from an incorrect assessment, the average risk R can be represented by the equation.

$$R = \sum_{i=k}^{m} P(S_k)P_kL_k$$

Amount of losses L_k inversely proportional to the prior probability:

$$L_k = \frac{1}{P(S_k)}$$

Minimization of average risk takes into account the average probability of the correct decision. Decision-making rules are reduced to calculating the likelihood ratio and comparing it with the threshold value. The criterion for minimizing average risk is manifested in the development of insurance options against exchange rate fluctuations by applying for a policy to an insurance company and currency clauses. The company, by concluding contracts with a fixed rate, compensates for the loss of funds caused by exchange rate fluctuations. Practical actions in this case are risk identification, situation assessment, deposit insurance through state corporations. Recommendations for using this criterion are conducting transactions with certain financial instruments to compensate for the possible negative effect of the onset of a currency crisis. This is achieved through diversification, i.e. investing funds in different assets to ensure minimal impact on portfolio profitability. The criterion of maximum a posteriori probability is used in cases where the a priori distribution of currency risk states is known, but there is no information on the amount of losses in the event of a crisis. The essence of the criterion is that of two solutions, the one corresponding to the largest value of the a posteriori probability is selected. This criterion is used when the loss matrix is unknown. Analytically, it is represented through observation x_n, which belongs to the class a_1, whose posterior probability is $P(a_j|x_n)$ and exceeds the posterior probabilities of other classes:

$$a = \begin{cases} a_2, & \text{если} \quad L(x_n) \geq P(a_1)/P(a_2) \\ a_1, & \text{если} \quad L(x_n) \angle P(a_1)/P(a_2) \end{cases},$$

$$P(a_j|x_n) = \frac{P(a_j)f\left(x_n|\ a_j\right)}{\sum_{k=1}^{K} P(a_k)f\left(x_n|\ a_k\right)}$$

The maximum a posteriori probability criterion manifests itself in the form of an increase in currency risk and the possibility of earning on exchange rate fluctuations by stimulating loans in currency at a reduced rate in the form of mortgages. The bank increases profits when the value of the currency increases. When the value decreases, the client wins. Recommendations for the use of criteria are its application in states of uncertainty of expected exchange rate fluctuations. Practical actions are the expansion of client interactions and interests. The maximum likelihood criterion consists of probabilistic estimates of the attribution of currency risk to the general state of the company. In this case, an incorrect assessment of possible losses is considered the most dangerous. The maximum likelihood criterion provides for estimating an unknown parameter by maximizing the likelihood function L in the case of a normal distribution with a fixed implementation. Likelihood is the probability of observed data with given model parameters. Threshold likelihood ratio $L_{пор}$ calculated through the ratio of the cost of losses q the cost of profit P.

$$L_{îïò} = \frac{q}{P}$$

Minimization of this value characterizes the desire to reduce incorrect assessments of the situation. For convenience of calculations, the logarithmic likelihood function is often used, which allows obtaining assessments that have good asymptotic properties, such as monotonicity of character and preservation of extremes. This simplifies the process of maximization.

In small samples, the maximum likelihood estimate satisfies the invariance property

$$L(x,\Theta) = \begin{cases} \prod_{i=1}^{n} P_i(X = x_i, \Theta) & \text{if } X \text{ is discrete} \\ \prod_{i=1}^{n} f(x_i, \Theta) & \text{if } X \text{ is continuous} \end{cases}$$

where Θ a fixed set of analyzed quantities, x_i a specific sample from the general population X, $L(x$, Θ – likelihood function.

The logarithmic likelihood function is found using the formula:

$$\ln L(x,a,b) = \frac{n}{2}\ln 2\pi - \frac{n}{2}\ln b - \sum_{i=1}^{n}\frac{(x_i - a)^2}{2b}$$

where a і b – coordinates of a point.

The Neyman-Pearson criterion is based on setting the admissible probabilities of various analyzed states. It is used to test the hypothesis about the correspondence of the empirical distribution of exchange rate fluctuations to the theoretical distribution with a large sample size. This criterion is used with a fixed time interval for decision-making with a given probability of an incorrect attitude to reality, when the onset of a crisis is not detected, and preventive actions have already been taken and the corresponding costs have been incurred. Two states are considered, one of which is under control. A certain threshold value is set, above which the losses exceed this value. Of all the admissible solutions, the optimal one is considered to be the one at which the average losses are minimal, and the gain is maximal. Depending on whether the outcome matrix is a gain matrix or a loss matrix, we have:

$f = \sum_{i\in D} P_i\alpha_i \to \max$ for the payoff matrix

$f = \sum_{i\in D} P_i\alpha_i \to \min$ for the loss matrix

where $\Sigma P_i = 1$, $P_i \geq 0$, $i = 1, m$, $D = \{i, \alpha_i \geq L\}$ – area of admissible solutions.

This criterion is manifested in the ability to reduce the overall currency risk through the use of financial instruments and various management strategies, by introducing business in different countries using different currencies. The recommendation is diversification, which reduces dependence on a specific currency. Practical actions consist of concluding transactions using different currencies.

DISCUSSION OF THE RESULTS OBTAINED

The criterion of the normal distribution of system states consists in choosing the optimal decision rule. This criterion is based on statistical analysis. It determines the probability that statistical data are subject to normal distribution. Normal distribution is a special type of distribution in which most of the values of the analyzed quantities are concentrated around the average. This type of criterion is based on the theorem, the essence of which is that the sum of a large number of independent random variables with a sufficiently large number of observations has a normal distribution. Normal distribution has two parameters, the mathematical expectation μ and standard deviation σ_x and for the value x is expressed as a function

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

In a normal distribution, its coefficient obtained by dividing the sum of all values by their total number should not exceed the standard deviation by two times. It is manifested in the development of adequate financial instruments for reducing risks in the form of currency clauses in transactions. Currency clauses consist of additionally introducing into export-import contracts settlements of amounts in a stable currency and including in the contract conditions on changing its value in the proportion in which the exchange rate changes.

Recommendations for the practical use of this criterion are the means of rapid response to changes in the exchange rate in order to avoid losses and invest in the currency of foreign partners.

The criterion for achieving a given level of reliability of the decision taken, states in determining the reliability and failure-free indicators, reflects the probability that the time of failure will be less than the specified operating time of the product. The main parameters involved in this criterion are:

– the probability of failure-free operation

$$P(t) = \frac{N(t)}{N} = \frac{N - n(t)}{N},$$

where N – total number of analyzed quantities;

$n(t)$ – the number of refusals, that is, incorrect assessment of the situation.

– mean time between failures or mathematical expectation of a series of consecutive values until the first incorrect certification of the current situation

$$T_{cp} = \frac{1}{N}\sum_{i=1}^{N} t_i ,$$

where t_I – time until the first misjudgment of the situation.

– failure rate as the ratio of the distribution density $f(t)$ to the probability of failure-free operation

$$\lambda(t) = \frac{f(t)}{P(t)}.$$

– distribution density as a statistical estimate of a random variable

$$f(t) = \frac{n}{N\Delta t},$$

where n – number of incorrect certifications.

It is used as a tool for protecting deposit security. It is especially useful for cases where the consequences of failure to take action when a crisis occurs and the resulting damage are incommensurate with reinsurance and false alarm about the onset of a crisis, when measures to prevent and reduce it have already been taken. This criterion is manifested in ensuring the possibility of minimizing currency risk. Recommendations for its use are the development of preventive measures to reduce losses from expected changes. Practical actions are the development of transactions and financial instruments for the formation of a reserve fund.

Harrington's interval desirability function criterion is based on modeling the correct estimates of possible states. It is manifested as a tool for correlation analysis with an assessment of confidence intervals and forecasts of currency risk fluctuations by determining the law of distribution of fluctuation randomness.

Harrington's interval desirability function criterion is used as an indicator of the reliability of performance and residual resource assessments. To do this, an artificial metric is introduced in which a set of reviews is put in line with a standard analogue, that is, the partial desirability of the function is calculated d_i.

$$d_i = \exp[-\exp(-y_i] = e^{-e^{-y_i}}$$

where y_i – the value of the i-th partial response converted to a dimensionless desirability scale $d_u(u = 1, 2, \ldots, n)$ (fig. 2).

The desirability scale has an interval from 0 to 1. $d_u = 0$ corresponds to an absolutely unacceptable level of quality, and the value $d_u = 1$ the best value (table 1).

The generalized desirability function is calculated as the geometric mean of the partial desirabilities.

$$D = \sqrt[n]{\prod_{i=1}^{n} d_i}$$

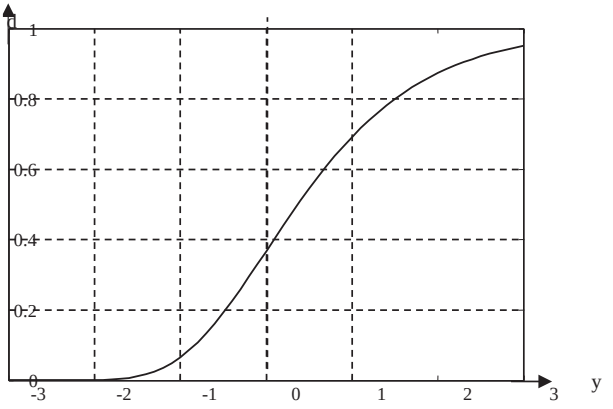

Fig. 2. Harrington's desirability function

where n – the number of characteristics of the state of performance of diagnostic objects under consideration.

Table 1. Interval scale of quality of performance indicators of diagnostic objects

Rank	Quality	Interval of numerical values
1	Excellent	0,8–1,0
2	Good	0,63–0,80
3	Satisfactory	0,37– 0,63
4	Bad	0,20–0,37
5	Very bad	0

Practical steps for implementing this criterion are the use of accounting and management reporting data to measure the level of their influence. Recommendations include the construction of regression liquid models of target variable returns.

The criterion for assessing the root-mean-square error is based on measuring deviations from a stable state and is manifested as a tool for reducing currency risk for large companies operating in international markets by fixing the exchange rate for future payments. It is used as a complex financial transaction that requires financial preparation and support in the form of futures contracts and swaps. Practical steps for its use are hedging, planning financial transactions, managing cash channels, concluding transactions that compensate for potential losses from changes in the national currency exchange rate. Recommendations for their application are concluded upon detection of negative trends in the economy to protect corporate investments from devaluation of the national currency.

The classification of the economic essence of statistical criteria and their adaptation to assessing currency risk is presented in Table 2.

To determine the mathematical expectation and dispersion of exchange rate fluctuations, the initial data in the form of text files are presented as implementations of a random process, which are introduced into the MathCAD mathematical modeling system using the appropriate

Table 2. Classification of the economic essence of statistical criteria and their adaptation to the assessment of currency risk

Criterion name	Essence	Manifestation	Recommendations for use	Features and differences
Ideal observer criterion	Determining the probability of damages and losses based on observations	Neutral attitude to the problem	Restriction of currency transactions, introduction of limits on currency withdrawal from accounts	Small volumes of currency withdrawal transactions
Minimization of average risk	Measure of financial protection	Insuring against exchange rate fluctuations		Risk identification
Maximum posterior probability criterion	Getting income by increasing the bank's currency risk	Profit and loss fluctuations	Assessment of additional expenses for protection of funds	Uncertainty of expected changes
Maximum likelihood criterion	Ratio of probability estimates	Forethought of future payments		Development of preventive measures
Normal distribution criterion	Quantitatively measured features	Adjustment of export-import contracts	Identification and consideration of clients' interests	Optimization of marketing strategies
Neyman-Pearson criterion	Level of significance of the decision being made	Reducing currency risk through various strategies and instruments		Comparison with the threshold value
Criterion for achieving a given level of reliability	Indicators and guarantees of results	Formation of a reserve fund	Transactions that ensure stability of payments	Implementation of protective provisions and measures
Estimates of root mean square error	Determining the difference between the predicted and actual value	Hedging of financial transactions		Protection of corporate investments
Harrington's interval desirability function	Modeling interval estimates	Qualitative assessments of management	Prediction of values based on known data	Forecasting tools

functions for each forecasting period. After this, graphs and histograms of the probability density are constructed at the beginning, in the middle and at the end of forecasting to determine the non-stationarity of the processes. To construct spectral density graphs, it is necessary to determine the correlation function of the relationship between two values of a random variable at arbitrary points in time through Fourier transforms in order to establish at what forecasting segment the error will be minimal.

CONCLUSIONS

The use of statistical quality criteria in currency risk management models makes it possible to study more subtle properties of currency portfolio management processes: such as the volume of currency transactions, the limitation of currency transactions, the inclusion of conditions in export-import contracts on changes in value caused by exchange rate fluctuations.

The processing of statistical information comes down to determining probabilistic estimates of the quality of implementation of possible management options, which is achieved by methods of statistical decision theory.

Statistical methods of risk analysis are recommended for use when there is a sufficient amount of analytical and statistical information on the states of the object of analysis. The advantages of the methods are the ability to analyze and evaluate various event options and risk factors within a single approach.

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