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Application of Expert Information in Combining Economic Forecasts

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Abstract--- Subject: *Combining forecasting is one of the current alternatives to improve the accuracy of economic forecasts. Nowadays there are quite a lot of different options for constructing weight coefficients for combining forecasts, however, all of them are primarily based on statistical characteristics used by particular predictive models and in fact do not resort to applying expert information. Yet it is difficult to disregard the lack of its application in social and economic forecasting. The expert information in forecasting is a significant factor affecting its accuracy in the time of the call for universal use of all available information on the processes and promotions of the economics of digitization, as well as in the conditions of the strong dependence of economic phenomena on external factors.*

Purpose: *The consideration of the options for applying expert information in combining forecasts is of essential importance. Moreover, the process of construction of generalized integral indicators, which occurs directly with the use of expert information, is structurally close to the combining forecasts.*

Methodology: *The article discusses advantages and disadvantages of the most popular approaches for constructing integral indicators based on expert information, as well as the opportunity of using such approaches in combining forecasts; the authors also propose to consider an approach dissimilar to the traditional use of expert information.*

Result: *All the presented approaches for combining forecasts with the use of expert information are summarized in a general table; the latter was designed to assist in interpreting the applicability of expert information in combining forecasts, as well as to identify the possible trends in improving the use of expert information in forecasting.*

Conclusions: *Following the obtained data on the proposed methods for combining forecasts with the use of expert information, conclusions can be drawn about the feasibility of using one or another approach in order to improve the accuracy of economic forecasting.*

Keywords--- *Combining Forecasts, Economic Forecasts, Expert Information, Pairwise Comparison Method, Integral Indicator.*

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I. INTRODUCTION

To date, the methods of using combining forecasts to improve the accuracy of forecasting are encountered in practice with increasing frequency [1, 2]. Combining forecasts is quite an effective way to utilize data on the predicted process, obtained by various particular methods of forecasting with the aim of its subsequent merging into a single result [3].

Existing methods for constructing weights in combining forecasts are based only on information on the previous accuracy of particular forecasting methods. The post-data only is no longer enough to predict the future situation under the conditions of a constant change in the dynamics of economic processes influenced by the external factors; in such conditions, the effectiveness of using conventional statistical forecasting methods decreases. To improve the accuracy of forecasting, it is essential to anticipate future events that may affect the process being studied. Under certain conditions in the future, this foresight can be expert information, which would allow correcting the obtained forecast depending on the assessments of the behavior of the process being studied. Moreover, it should be acknowledged that today, in the era of the digital economy and the digitalization of society, economic processes more than ever depend on a large number of social, political, environmental and other factors, and therefore are influenced by a large volume of various information. Thus, it is necessary to pay considerable attention to the use of expert information in increasing the accuracy of economic forecasting.

Combining forecasts, as the most developed trend in improving forecasting accuracy, also faces the problems of its improvement with the increase in data flow and due to other various factors that may affect the projected process. At the same time, combining forecasts is a method of improving the accuracy of forecasting based on the forecaster's evaluation of varying information available [4].

Therefore, in order to correct the shortcomings generally associated with combining, it is essential to further develop the methods of combining forecasts. Such development can be considered as the proposal of new methods for combining forecasts [5], which would take into account all the shortcomings [6], as well as apply additional expert information as a particular resource while improving the accuracy of forecasting.

Considering the approach of applying additional expert information, combining forecasts may involve both expert forecasting methods and methods for determining a generalized integral indicator that will act as particular methods for constructing weights in combining forecasts, and also the expert estimates that will act as auxiliary methods. In addition, the expert information expressed in the evaluated value of the process under review can be used as one of the elements of the combined forecast, which, however, requires past process evaluations.

The purpose of the presented study is to consider the opportunity of using additional expert information in combining forecasts as an additional factor for increasing its accuracy. Such an opportunity can directly serve as methods for constructing integral indicators based on expert information.

It should be expressly indicated that the conducted study reviewed the front-end statistical methods with the use of expert information as an additional tool; the study did not consider methods using expert estimations or surveys as such.

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II. MATERIALS AND METHODS

The approach to combining forecasts is quite simple; it involves deriving a single general forecast from several particular ones (built by particular forecasting methods) that would be weighed in a certain way. An overview of the combined forecast can be represented as:

$$F = \sum_{i=1}^{n} w_i x_i \qquad (1)$$

where x_i is particular forecasts obtained from **n** different forecasting methods, and w_i – weight coefficients. The linear form of combining forecasts is the most common in use, although it is not the only one. Weights represent a certain amount of information and accuracy in the pool of forecasts that are presently being originated from a specific forecasting method [7].

Particular forecasts are most often not differentiated; combining forecasting usually just conducts simple averaging of all available individual forecast results [8]. A simple average of several forecasts can indeed be better than the particular forecasts that were included in the combination, especially if the combination does not reveal the most appropriate and accurate forecast [9]. Yet such an approach does not always allow improving the accuracy of forecasting with respect to the particular forecasting methods used. It is quite logical to give more weight to a more accurate forecasting method since this method should have a larger share in the overall forecast [10]. From this point of view, the sum of the weighting factors should be limited from above and equal to one, i.e. the following condition should be imposed:

$$\sum_{i=1}^{n} w_i = 1 \qquad (2)$$

The necessity of this condition was well demonstrated in the work of Granger and Ramanathan [11]. In addition to the condition on the sum of weights, all the weights in the combined forecast should be positive from the point of view of the interpretation of weights as a share of information. Otherwise, negative weights or weights greater than one cannot be correctly interpreted. The task of combining forecast can be substantially represented as follows:

$$F = \sum_{i=1}^{n} w_i x_i$$

$$\sum_{i=1}^{n} w_i = 1 \qquad (3)$$

$$w_i > 0, i = 1, \dots, n$$

The methods of combining forecasts are quite diverse [12, 13, 14]. All their differences are based on the determination of weights for particular forecasts. The choice of one or another method for constructing weight coefficients in combining forecasts is always up to the researcher [15]. At the same time, the methodology for combining forecasts practically does not imply the use of expert information as an additional source for improving the accuracy of forecasting, although there is interest in developing this prospective area [16].

To date, a number of methods have already been developed using expert information; most of them are often used in practice. These methods are mainly applied as algorithms for constructing weight coefficients in the generalized integral indicator.

It is essential in combining forecasts to consider in detail the methods (and their application) of constructing the integral indicator, as well as to analyze their efficiency.

Existing methods are diverse in the use of expert information; also there is a need to assess the feasibility of their application in combining forecasts. They can be conventionally divided into two groups: methods that are used to build an integral indicator and other methods that use expert information that can be utilized to combine forecasts.

Such an assessment requires analyzing whether the use of one or another method of combining forecasts with the involvement of expert information will lead to improved forecasting accuracy.

III. RESULTS

3.1. Methods for Constructing an Integral Indicator in Combining Forecasts

Combining forecasting and constructing an integral indicator with the help of expert methods are quite similar tasks. The easiest way to determine weights through expert information is the use of *point rating methods and ranking methods*.

The idea of ranking and point rating methods is to assign each of the particular forecasts with a certain point relative to its accuracy of forecasting. The higher the forecasting accuracy, the greater the score (from zero to one) achieved by the forecast. Further, in order to obtain the weighting factors for the prospective combining, it is necessary to normalize the rated points against their sum. Thus, the conditions on the positivity of the weights and on their sum, which should be equal to one, will be satisfied.

The method based on the use of *Fishburn model* [17] deserves special attention since its essence also represents one of the ranking methods. In this case, the ranking is performed on the basis of statistical characteristics, which improves the forecast accuracy with respect to other methods of ranking and point rating.

First Fishburn Formula:

$$w_i = \frac{2(m-i+1)}{m(m+1)}, i = 1 \dots m \qquad (4)$$

where **m** is a number of particular forecasting methods, and **i** – the rank of a particular forecasting method; the ranking can be carried out against the accuracy of the methods. The first rank is to be assigned to the more accurate method of forecasting, the last one, correspondingly, to the less accurate.

Second Fishburn Formula:

$$w_i = \frac{2^{m-i}}{2^m - 1} \qquad (5)$$

Third Fishburn Formula:

$$w_i = a_i + \frac{1-\sum_{i=1}^{m} a_i}{\sum_{i=1}^{m}(b_i - a_i)}(b_i - a_i) \qquad (6)$$

where $a_i \leq w_i \leq b_i$ are the intervals of possible values for the weighting factors proposed on the basis of expert judgment. In this case, besides the ranking, expert information regarding the intervals of possible values is also required.

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The *method of pairwise preferences (comparisons)* can also be attributed to the methods of combining forecasts with the application of expert information. This method is quite well-known; it is often used in practice both for obtaining a general integral indicator and for identifying priority indicators [18, 19]. In addition, the pairwise comparison method is a fairly common method used in combining forecasts.

Gupta and Wilton described the matrix of pairwise preferences as a tool for finding the optimal weights for the combined forecast [20, 21].

The essence of such a method is as follows. Suppose the 'true' weights are given by the vector $\alpha = (\alpha_1, \alpha_2, \ldots, \alpha_n)$, where α_i ($i = 1, \ldots, n$) is theoretically the best weight assigned to the *i*-th quotient. Then the probability that the particular index *i* is more 'preferable' (less variance in forecasting) then the partial index *j* can be calculated by the formula α_i/α_j. The matrix of 'pairwise preferences' among particular indicators, in this case, will be described as follows:

$$O = \begin{pmatrix} \frac{\alpha_1}{\alpha_1} & \cdots & \frac{\alpha_1}{\alpha_n} \\ \vdots & \ddots & \vdots \\ \frac{\alpha_n}{\alpha_1} & \cdots & \frac{\alpha_n}{\alpha_n} \end{pmatrix} \quad (7)$$

Each o_{ij} record can be interpreted as the probability of preferring the particular indicator *i* to the indicator *j*. Note that each element of the matrix is positive and that $o_{ij} = {}^{1}/_{o_{ji}}$, and the diagonal elements are equal to one. Therefore, $O\alpha = n\alpha$. Knowing matrix *O*, the weights vector α is provided according to the solution $(O - nE) = 0$, where *E* is an identity matrix. Since matrix *O* has a unit rank and its trace is equal to *n*, then only one of the eigenvalues is non-zero, and it equals *n*. Thus, this matrix of 'pairwise preferences' is compatible and can always be solved with respect to α. Certainly, matrix *O* must first be evaluated.

The advantage of this method is that the evaluation of the matrix can be performed in various ways depending on the objectives of the study. In practice, the method of 'pairwise preferences' uses an estimate based on how many times one or another particular forecasting method was more accurate or preferable than a different particular forecasting method compared with. Various data may be used to evaluate the matrix of pairwise preferences, including that obtained on the basis of expert estimates [22].

Similar to the method of pairwise preferences is the method of analyzing hierarchies by the Saaty algorithm [23]. This method is essentially different from the method of pairwise preferences by defining a matrix of pairwise preferences. But this method will be inferior in accuracy to the method of pairwise preferences due to the subjectivity of determining the matrix of pairwise preferences.

Another option for applying expert information in combining forecasts is to use the data on confidence limits of the process under study. In this case, expert estimates are used not to obtain a combined forecast but to determine possible forecasting results. Resting on their experience, the experts involved determine the possible boundaries (confidence intervals) for the combined forecast; the further forecasting is already carried out with respect to this information. Confidence intervals are of great importance in socio-economic forecasting, since it is a common

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practice that there might be several alternative options for the future bearing of the process being studied, yet all these options have to be considered in forecasting.

Also noteworthy is the method of randomized aggregated indicator proposed by N.V. Khovanov [24]. This method does not require all the numerical information about the process being studied; it uses non-numeric, inaccurate and incomplete expert information (NII-information). The aggregate indicator is built here on the basis of an assessment of the weighting factors at the probability with which this or that event will occur.

3.2. The Alternative Application of Expert Information in Combining Forecasts

Except for the cases when the integral index building approaches are used to combine the forecasts, expert information may be applied in other ways. Thus, expert information can be used as an estimate of the confidence intervals of the predicted results.

In the case of using expert estimates as a definition of confidence intervals, additional restrictions on the forecast results are added to the task of determining the combined forecast. V.B. Golovchenko and S.I. Noskov suggested using expert information for defining a general forecast in two possible scenarios [25]:

1. The deterministic problem where the experts were engaged only in relation to the possible intervals for the predicted process; in this case, a simple linear programming problem (3) is solved using additional constraints.
2. The probabilistic problem where the experts also suggested estimates of probability; in this case, the conditions associated with the probabilistic characteristics of the information received from the experts are added to the linear programming problem (3).

The proposed approaches are fairly simple in calculations and can be used for a wide range of different tasks. But since these approaches, as originally stated, have application only in determining the confidence intervals of the combined forecast, they cannot directly affect the forecasting accuracy. Still, these approaches can be an additional tool if there is expert information that needs to be involved in the forecasting.

The above-described methods for determining the weights use the estimates of experts in their calculations. Unfortunately, these methods are quite subjective and highly dependent on the competence of experts. However, as the data affecting the process being studied, one can consider not only expert evaluations of the predicted process but also other processes and even evaluations of these processes. So, being aware of the level of interrelation between two processes, it is possible to determine the adjusting coefficient for the combined forecast of the process in question. Consequently, whether the two processes are subjected to the same dynamics, then by evaluating one of these processes an assessment for the other one can also be obtained. Nevertheless, such accomplishment required mutual cointegration of the time series describing the studied processes.

The cointegration of time series is usually interpreted as a situation where the series has a similar trend and kept the close proximity from each other over time. A more mathematical definition of cointegration is the following: if some linear combination of two-time series has an integration order smaller than the integration order of each of the series, then they say that the time series are co-integrated [26]. The very cointegration between time series can be

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determined using the Johansen test, which is implemented in many statistical software packages. Thus, if an indicator with similar changes over time is selected to combine the forecasts of diverse time series, its changes can be taken into account in forecasting of the initial time series.

The method of forecasting with the use of information from co-integrated time series is also quite simple. At the first stage, the time series is determined, which will be used for subsequent forecasting. Such a series should be cointegrated to the combination of forecasts, which is used in the study, and should have sufficiently accessible information on the predicted dynamics of changes.

Now and in the sequel, the adjusting coefficient between the integration of forecasts and its co-integrated time series is determined, which defines the relationship between them. Such a coefficient will be able to further adjust the dynamics of combining forecasts based on data available. In this case, the form of the combined forecast will be as follows:

$$F = \gamma(\sum_{i=1}^{n} w_i x_i)$$

where γ is the adjusting coefficient.

Correction and recalculation of the adjusting coefficient should be performed at each subsequent forecasting step with the participation of new data. Herewith, for the calculation of the adjusting coefficient, more than one time series or factor affecting the process under study can be applied.

The adjusting coefficient itself can be obtained, for example, through the ratio of the change in the co-integrated time series to the time series on which the combined forecast is based.

Thus, with the identification of external factors that may affect the process being studied and assessment of their impact, it is possible to eliminate the co-integrated time series while adjusting the combined forecast and correct the forecast only on the basis of certain factors.

IV. DISCUSSION

As can be noted from the consideration of methods for constructing integral indicators as a supplement to combining forecasts, not all the considered approaches will lead to an increase in forecasting accuracy. Some particular conclusions drawn from the analysis of the methods described above deserve a special focus.

Considering the methods of ranking and point rating, this approach will lead to particular methods deterioration in the accuracy of forecasting. This is primarily due to the fact that the ranking and points do not allow for a qualitative assessment of particular forecasting methods, due to which the weights are not distributed relatively to particular forecasts. Weights with this definition will be approximate and subjective. More accurate individual forecasts are often undervalued.

Thus, in most cases, when applying the ranking or point rating approach in four combined particular forecasts, the most accurate forecast will always have a weight of 0.4, and a less accurate - 0.1. Therefore, these values will be constant and, in fact, will not reflect the real contribution of individual forecasts to the combined one. For this

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reason, the methods of ranking or point rating are not suitable for use in constructing the weights of the combined forecast.

The Fishburn model allows giving more weight to a more accurate method of forecasting as to the most important method. But building weight coefficients using Fishburn formulas also does not provide the necessary increase in forecasting accuracy, since even the first in the ranking method of forecasting will be given an underestimated weight, which will affect the accuracy. That is, a more accurate particular forecast will receive a weight, which will be less than that which could be calculated on the basis of the usual methods of combining forecasts. This is clearly seen in the first two Fishburn formulas, by which it is possible to obtain weights similar to weights with the usual ranking of particular forecasts. In addition, if the forecasts in the ranking have sufficiently close values, they will be given weights that differ greatly among themselves. The third Fishburn formula, which allows (based on expert assessment of the boundaries for weights) to give more accurate weights for individual forecasts, may appear more suitable for combining forecasting.

Just as in the case of simple ranking, the weights, according to the first two Fishburn formulas, will always be constant, depending on the number of particular forecasting methods and regardless of the accuracy of the very methods used in the combination. For the third Fishburn formula, it will be important to specify the boundary conditions for the weighting factors, which can be done on the basis of expert estimates.

For example, we can likewise compare the weights obtained for four particular forecasting methods. The results can be seen in *Table 1*.

Table 1: Determination of Weights Using the Fishburn Formulas

	1st Fishburn formula	**2nd Fishburn formula**	**3rd Fishburn formula**
Method 1	0.4	0.533	0.832
Method 2	0.3	0.267	0.132
Method 3	0.2	0.133	0.023
Method 4	0.1	0.067	0.013

In the example above, the most accurate methods fell from the first to the last. In the case of using the first Fishburn formula, the result similar to the use of simple ranking was obtained. With the second Fishburn formula, the result was more suitable; however, the accuracy of such forecasting will be insufficient. In the third Fishburn formula, special bounds were used for weighting factors: method 1 – from 0.8 to 0.9; method 2 – from 0.1 to 0.2; method 3 – from 0.01 to 0.03; method 4 – from 0.01 to 0.02.

Thus, an estimate of the boundaries for the weights in the third Fishburn formula may allow its use in combining forecasts.

From the point of view of improving the accuracy of forecasting, the method of pairwise preferences can show quite good results. But this method is still closer to the statistical methods for combining forecasts, although this method in its calculations may employ the construction of a pairwise preference matrix based on expert estimates.

The Khovanov method of a randomized aggregated indicator is difficult to use and requires software implementation. But at the same time, this method does not depend on the inaccuracy of the data used and the subjectivity of expert judgment; and is often used in practice [27]. It can also be applied in combining forecasts. But in such a case, not their values but their estimates of the likelihood that the actual value will be equal to this or another forecast value will be used as a particular forecast.

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All the methods described above can be summarized in a general table (*Table 2*). The table presents all the advantages and disadvantages of the methods for constructing integral indicators that can be used to build weights in combining forecasts and which were described in this paper.

It stands to mention that, naturally, these are not the only methods that can be used in adjusting the results of a combined forecast, however, these methods are the most common in economic practice and do not require additional expert surveys, which can be quite difficult to carry out and apply in combining forecasts.

Table 2: Methods for Combining Forecasts Using Expert Information

Method	**Description**	**Advantages**	**Disadvantages**
Ranking method and point rating method	The simplest methods using the ranking of particular forecasts for their accuracy	Do not require additional information on the process; more accurate particular forecasts receive more weight.	Do not lead to increased forecasting accuracy. The weighting coefficients are calculated on the basis of the assessment issued, with no respect to information on a particular forecasting method. Weights with a large difference in value correspond to the close-value forecasts.
Fishburn Formulas	More correct distribution of assessments for particular forecasting methods regarding ranking and point rating methods	Also represent the simple methods of applying expert information in combining forecasts	Also have a low increase in accuracy with respect to the simple averaging of particular forecasts; possess the same shortcomings as point rating and ranking methods
Pairwise preferences method	Each of the particular forecasts is evaluated by preference over other forecasts. The matrix of preferences is built premised on all the estimates; each element of the matrix is the preferred weight for a particular individual forecast. In addition to expert assessments, information on the accuracy of a particular forecasting method can be used to evaluate the matrix of preferences	The method involves a different assessment of the matrix of preferences, which makes it a universal method using expert information. It is a programmable method; it leads to an increase in forecasting accuracy with respect to particular methods. The method does not require a large amount of information on the process under study. A fairly flexible method, correcting its results with respect to the new information received. Well suited for the application of expert information.	Less accuracy compared to other methods of combining forecasts
Method of randomized aggregated indicators	Based on all available information on the process under study, which is presented as non-numeric, inaccurate and incomplete, weighted estimates are calculated in a general aggregated indicator. Weights are estimated based on a random selection of all possible variations of weights; as for the function of the indicators themselves, there are probabilities in weights, that the real data will be equal to this indicator.	A fairly effective method of adjusting the combined forecast using several types of expert information. Does not require knowledge of complete accurate numerical information on the process under study.	A necessity to apply several types of expert information. The method itself requires software implementation and cannot be applied without the necessary knowledge of the methodology; also notable by the complexity of calculations
Application of expert information to determine boudary intervals	Engaging experts to determine the maximum and minimum values for the combined forecast. Then the task of combining is reduced to solving a linear programming problem with constraints.	Does not require large amount of expert information	Required expert information on the boundary intervals of the process being studied in the future
Application of co-integrated time series	Calculation of adjusting coefficient to combine forecasting with the use of another co-integrated time series; the dynamics of the known time series is transferred to the dynamics of the studied series.	Adjustment of the resulting combined forecast based on expert information; quick adaptation of the adjustment coefficient to external changes; refinement of the combined forecast in use regarding external influencing factors.	Low forecasting accuracy; the adjusting coefficient may depend on factors that will not affect the process being studied.

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V. CONCLUSION

There are many quite effective methods of forecasting in the modern economic paradigm. In this regard, a large role is given to the improvement of these methods and increasing their accuracy, including through the application of various available information for forecasting.

Combining forecasts is quite an effective and reliable way to improve the accuracy of information, especially in conditions of uncertainty in the choice of a particular method of forecasting. However, even the combined forecast requires further improvement.

The application of various sources of information in economic forecasting and planning under the period of booming digital and information economy is of essential importance. The economic forecasting is no longer possible with the application of only the statistical tools and without calling upon expert information and expert assessments. In this regard, it is also necessary to apply expert information in combining forecasts.

Such expert knowledge in combining forecasts can serve as information on the accuracy of a particular forecasting method, as well as information on related processes that may affect the forecasted indicator.

To date, there are some approaches with the application of expert information that could be used in constructing the weights of the combined forecast; however, not all of them can improve the accuracy of forecasting. The authors are entitled to the opinion that the most optimal method for combining forecasts with the use of expert information is the pairwise preferences method and the third Fishburn formula, although these methods use more statistical data on the process under study, rather than directly the expert information.

This may indicate that so far there are no approaches that would allow applying all the available information (including expert knowledge) at the fullest extent in combining forecasts. Existing methods and attempts to apply expert information are still based mainly on statistical approaches. In this regard, further scientific development in the field of application of the expert information in combining forecasts is highly relevant and deserves more attention.

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