Analysis of Electricity Pricing in Emerging Economies With Hybrid Multi-Criteria Decision-Making Technique Based on Interval-Valued Intuitionistic Hesitant Fuzzy Sets

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ABSTRACT This study aims to analyze the factors that influence electricity prices. For this purpose, a hybrid multi-criteria decision-making (MCDM) model based on interval-valued intuitionistic hesitant fuzzy (IVIHF) sets is proposed. Firstly, a large literature review is carried out and 10 different factors that can affect electricity prices are determined. After that, IVIHF decision making trial and evaluation laboratory (DEMATEL) methodology is considered to find which factors are more significant in electricity prices. The finding shows that inflation rate and technological improvement are the most important criteria that affect electricity prices. Thus, the countries should consider expected future inflation rates to take necessary precautions to minimize volatility in electricity prices. Moreover, countries should follow current technologies regularly and make effective research and development to provide electricity with lower prices. In the second stage of the analysis, emerging 7 (E7) economies are ranked with respect to the performance related to the management of electricity price volatility. In this context, IVIHF VIšeKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) approach is considered. It is concluded that Russia and China are the most successful countries in keeping electricity prices away from volatility whereas India and Turkey get the latest order. Furthermore, a comparative evaluation is also implemented by considering IVIHF technique for order preference by similarity to ideal solution (TOPSIS) methodology to check the consistency of the analysis results. The results of both approaches are quite similar which gives information about the consistency of the ranking results. On the other hand, a sensitivity analysis is performed to ten different cases consecutively. It is determined that the ranking results are coherent by considering the changes in the criteria weights.

INDEX TERMS Electricity prices, IVIHF DEMATEL, IVIHF VIKOR, IVIHF TOPSIS.

I. INTRODUCTION

Electricity is so crucial for countries' developments by satisfying basic human needs and pursuing production. Therefore, for accurate electricity pricing, it is very significant to determine factors that affect this pricing. Hence, strategic precautions can be implemented when volatility can be

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identified for the future price [1]. There can be many factors that affect electricity prices. For example, in energy-dependent countries, volatility in exchange rates can cause undesirable changes in prices because they import most of their energy demand from abroad [2]. Another important point is that inflation causes an increase in electricity prices [3]. The main reason is that there is increase in prices of many different products and services due to inflation. This situation also increases the price of the raw material from which

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electricity is produced, so the high inflation rate leads to an increase in electricity prices in the future terms. Industrial development also affects electricity prices in a country [4]. If the industrial production of the countries is going up, the need for electricity will increase. If the electricity in the country is insufficient to meet the production levels, there will be excess demand, and this will cause the increase in electricity prices. Political factors in the country can also have an impact on electricity prices [5]. For example, taking the privatization decision in electricity generation may cause prices to fluctuate, since electricity prices will be determined in the free market [6]. In this case, it will have an increasing effect on price fluctuation. Consumption habits can be one of the determinants of electricity prices. For instance, a person who chooses a stove for heating may influence general electricity prices.

The number of electricity suppliers can also have an impact on electricity prices [7]. In this context, there are important differences between having a single electricity supplier and having many. While a single supplier can be very effective on the price, this power decreases when there are too many suppliers. In addition, the financial strength of its suppliers also has an impact on electricity prices. If electricity suppliers experience financial difficulties in general, changes in electricity prices will occur as the volatility in the market will increase. Moreover, changes in weather conditions can also affect electricity prices. For example, in a period when the weather is extremely cold, the demand for electricity will go up. Furthermore, similar to the weather conditions, changes in geographical conditions can also affect electricity prices [8]. For instance, it will not be easy to supply energy to very mountainous places, which increases the volatility in the price. On the other side, thanks to the technological developments, it is possible to produce electricity cheaper [9]. In cases where these developments cannot be followed effectively, electricity prices will be unnecessarily high. As a result, the industry and economy of the country will be negatively affected.

In this study, the main factors that affect electricity prices are analyzed. Within this context, firstly, 10 different factor that cause changes in electricity prices are determined by making a literature research. Later, an examination is conducted with IVIHF DEMATEL method to give weights to the criteria set. In addition, E7 countries are also evaluated for the management of electricity prices with the help of IVIHF VIKOR method. In this process, those weighted criteria are considered. IVIHF TOPSIS method is also considered to rank these countries with the aim of making a comparative analysis. Moreover, sensitivity analysis is also implemented with 10 different cases to check the coherency of the ranking results. The main reason of selecting E7 countries is that they have an intense industrial development process to achieve economic development. Within this framework, electricity prices are an important factor in these economies because electricity is used as a significant input in the production process. Hence, the factors that cause volatility in electricity

prices must be understood correctly especially for these countries.

This study has many different novelties. First, the analysis results can be very helpful for developing countries to take necessary actions to prevent volatile electricity prices. Additionally, owing to the analysis results, it can be much easier to overcome unexpected electricity price shocks. Thus, it is believed that these results will be guiding for both researchers and policy makers. Another important novelty of this study is that IVIHF DEMATEL and IVIHF VIKOR are considered in the analysis process together. By using this hybrid approach, it is believed that the methodological originality of this study increases. Moreover, with the help of using DEMATEL approach, impact relation map of the factors can be generated [10]. This situation provides an opportunity to make causality analysis between the variables. Additionally, the main advantages of VIKOR methodology is the ease of use and flexibility. Also, maximum utility and minimum regret are taken into consideration so that it helps to reach more appropriate results [11]. On the other side, owing to the consideration of IVIHF sets, it can be possible to minimize uncertainty and ambiguity in complex decision-making environment [12], [13].

This study includes 6 different sections. In the first part of the study, the factors that can cause changes in electricity prices are explained. Moreover, in the second section of the study, a literature review is conducted on determinants of electricity prices. In addition, the third part of the study contains the theoretical knowledge of IVIHF DEMATEL, IVIHF VIKOR and IVIHF TOPSIS methods which are used in the examination process. In the fourth section of the study, the results of the examination are explained. Furthermore, the fifth section gives information about the discussion and conclusion. In the final section, the limitations and future research directions are underlined.

II. LITERATURE REVIEW

In this section, firstly, necessary information is given regarding the studies in which indicators of electricity prices are evaluated. Secondly, the literature for the methodology is also reviewed.

A. LITERATURE ON FACTORS THAT AFFECT ELECTRICITY PRICES

In the literature, it is accepted that the exchange rate is one of the main factors that affect electricity prices. Since countries without natural resources supply their energy from outside, electricity is one of the commodities traded in dollars for these countries. Therefore, the effect of the dollar on electricity prices can be seen directly [14]. Muñoz and Dickey [15] evaluated electricity prices in Spain by using Engle-Granger cointegration analysis and concluded that changes in exchange rate causes a volatility in electricity prices. In the other hand, Adom [16] studied the dynamic effects of a hydro-based technology on electricity prices in Ghana by using Granger causality analysis. It is determined that there
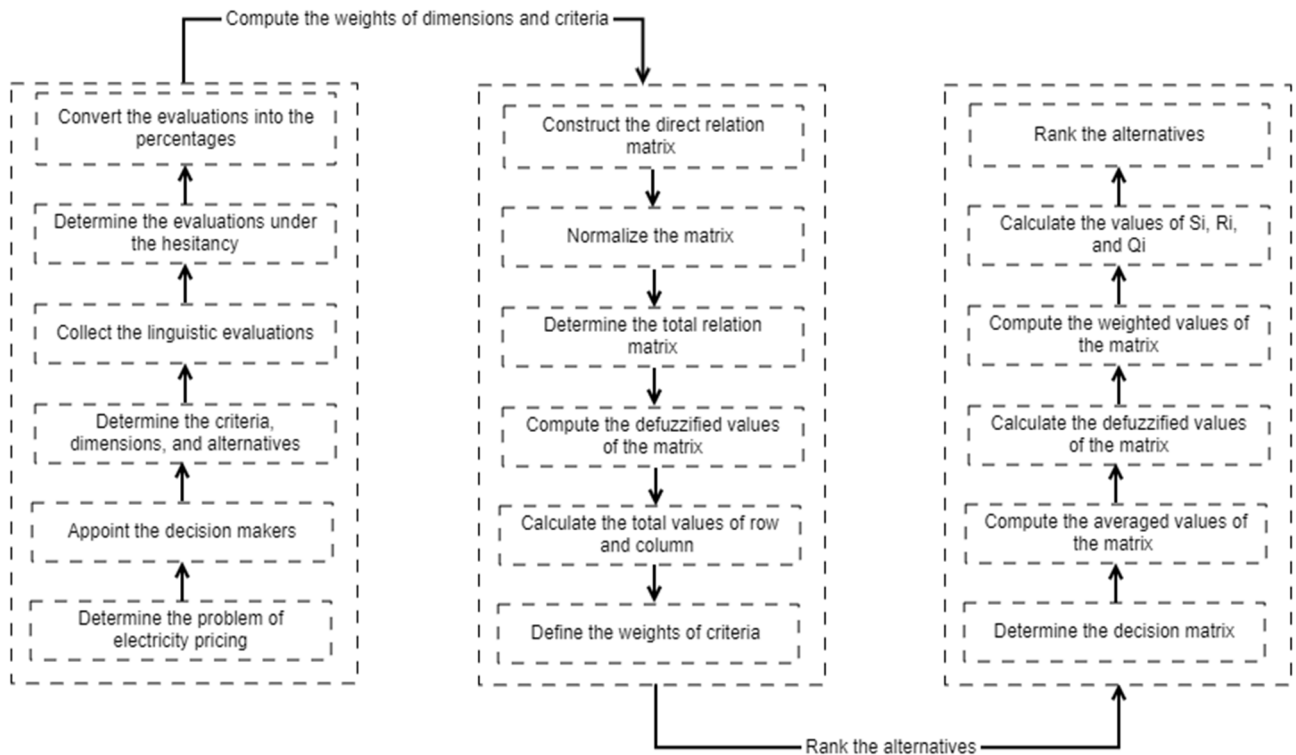
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FIGURE 1. The algorithm of the proposed model.

is a strong relationship between exchange rate and electricity prices. Another factor which affects electricity pricing is inflation rates. The price of electricity also reflects production costs, which depend on other things, such as inflation rate. Inflation can cause an increase in electricity prices [17]. Haratian *et al.* [18] focused on the electricity prices in Iran with the help of optimization methodology. They reached a conclusion that inflation rates could increase the cost of energy which leads to higher electricity prices. Ndou and Gumata [3] also stated that inflation rate has persistence effect on electricity price in recent years. Industrial production has also impact on electricity prices. If a country's industrial production is increasing, its need for electricity will increase. If the electricity in the country is insufficient to meet the production of electricity, there will be excess demand for electricity, and this will cause electricity prices to increase [19].

Electricity pricing is additionally influenced by political factors. For example, privatization decision in electricity production may cause increases or decreases in electricity prices. Adel *et al.* [20] focused on electricity market in Saudi Arabia with price estimator modelling. They defined that a well-established privatization caused electricity prices to go down and an increase in the quality of services. However, some studies suggest that there is no relationship between privatization and electricity prices [21], [22]. Consumption habits are one of the effective factors for electricity prices. Bardazzi

and Pazienza [23] examined European population in their study with survey methodology. They stated that older people prefer thermal comfort in their home. Furthermore, they stay home longer than young people and it increases their heating and air conditioning demands. This situation leads to an increase in electricity energy consumption. Supplier facilities are another factor that influences electricity prices. Single or few numbers of electricity supplier can act as a monopoly and cause volatility in electricity prices [24]. Özbuğday *et al.* [25] examined Turkey's reshaping electricity sector and defined that the financial strength of its suppliers also has an impact on electricity prices. Kaller *et al.* [26] evaluated the energy markets in European countries by using the Blundell-Blond System GMM estimator. They indicated that if electricity suppliers experience financial difficulties in general, this will significantly affect electricity prices as volatility in the market will increase. Weather conditions additionally influences electricity prices. Yukseltan *et al.* [27] tried to forecast electricity demand for Turkey with the help of regression analysis. They determined that irregular weather conditions have impact on energy demand forecasting, so does electricity prices. Genc [28] focused on Ontario wholesale electricity market by making GMM estimation. It is found that weather conditions such as heat waves or unexpected cold days have a significant influence on the electricity prices.

Electricity prices can also be affected by technological improvements. Deng *et al.* [29] studied the electricity prices

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in China by using regression methodology. It is identified that technologic progress has impact on electricity production and consumption. In the other hand, Mai *et al.* [30] showed that technology reduces carbon emission cost, so this cause electricity price to decrease. Furthermore, environmental concerns have impact on electricity prices. Tziogas *et al.* [31] stated that environmental concerns have an impact on electricity generation and price. Paladino and Pandit [32] used attribution theory and indicated that environmental degradation causes increase in renewable energy consumption and price has impact on sustainable consumption behavior. Hence, governments and organizations try to appeal renewable energy for customers and to increase purchasing green energy behavior with different strategies such as sustainable branding, innovations, or customer-oriented approach. Also, government and retailers can help customers to manage their electricity consumption and bills and importance of green electricity for environment could be explained to customers. In addition to them, some researchers also underlined the importance of the control mechanism of the grid. Electricity network is a composite network created to transmit the generated electrical energy to users. Therefore, any problem in this system will adversely affect the efficiency of the electrical energy to be obtained [33]. In this context, it is important to make the necessary checks on this network and to detect the presence of a potential problem early. This will prevent volatility in electricity prices [34].

B. LITERATURE ON THE METHODOLOGY

In this study, DEMATEL approach is considered to find the significance levels of the factors that affect electricity prices. This approach has many benefits over similar methods, such as analytical hierarchy process (AHP) and analytical network process (ANP). For instance, impact relation analysis can be performed with DEMATEL. With the help of this issue, the causality relationship between the criteria can be evaluated. Because of these advantages, this approach was considered by many different studies in the literature. Most of these studies used this approach with fuzzy set. For example, Lin *et al.* [35] made a study regarding supply chain management, Mavi and Standing [36] focused on project management and Sangaiah *et al.* [37] evaluated the knowledge transfer effectiveness with the help of fuzzy DEMATEL. This methodology was also considered with IVIHF sets, but these studies are very limited. For instance, Zhang *et al.* [38] aimed to understand the main factors of youth unemployment by using this methodology. Abdullah *et al.* [39] focused on solid waste management and the criteria are weighted with this method.

In addition, VIKOR approach is also used in this study with the aim of ranking E7 economies regarding the effectiveness of the management of electricity price fluctuations. It is also possible to mention some advantages of this method. In this context, the main benefit of VIKOR methodology is the ease of use and flexibility. Furthermore, maximum utility and minimum regret are considered. Owing to this

aspect, more appropriate results can be achieved with the help of this method. Due to these benefits, lots of researchers considered this methodology in their studies with fuzzy logic. Safari *et al.* [40] used fuzzy VIKOR approach to rank enterprise architecture risks. Gul *et al.* [41] also focused on the risks in mine industry by this methodology. Additionally, Liang *et al.* [42] evaluated the quality of the internet banking website with the help of this method. However, there are very limited studies in the literature which use fuzzy VIKOR with IVIHF sets [43], [44].

C. THE RESULTS OF LITERATURE REVIEW

As a result of the literature review, it is defined that there are many studies in the literature focusing on the determinants of electricity prices. It is seen that different issues such as inflation, exchange rate, political factors and climate conditions may have an impact on electricity prices. Another result reached is related to the methods used in the studies. Econometric methods such as regression and cointegration were generally used in these studies. The biggest disadvantage of this type of analysis is that it cannot consider variables without numerical data. Therefore, the greatest need in the literature for this issue is to carry out a new analysis in which factors without numerical data can be taken into consideration. In this context, both numerical and non-numerical variables that can affect electricity prices were determined in this study. In the analysis made with the IVIHF DEMATEL method, all these variables could be considered. Thus, this study is quite different from other studies in the literature. On the other hand, IVIHF DEMATEL, IVIHF VIKOR and IVIHF TOPSIS methods have been considered for the first time in this study in terms of electricity prices as hybrid. It is concluded that this situation also increased the originality of the study.

III. METHODOLOGY

In this section, firstly, interval-valued intuitionistic hesitant fuzzy sets are explained. After that, IVIHF DEMATEL approach is defined. In the next part, necessary information is given for IVIHF VIKOR methodology. Finally, IVIHF TOPSIS approach is detailed.

A. IVIHF SETS

The intuitionistic fuzzy set was introduced by Atanassov as a generalization of the fuzzy set [45]. The main benefit of this set is that it can be more possible to deal with the uncertainties in decision-making process in comparison with the classical fuzzy sets. Because of this positive issue, it became very popular in the literature. For instance, Tuzkaya *et al.* [46] evaluated the hospital service quality by using interval-valued intuitionistic fuzzy PROMETHEE. Similarly, Seker and Aydin [47] focused on the sustainability of the public transportation system with the help of interval-valued intuitionistic fuzzy AHP.

Definition 1 [48]: Let $S = \{s_0, \cdots, s_\tau\}$ be a linguistic term set. A hesitant linguistic fuzzy set (H_S) is defined as in the

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equation (1).

$$H_S = \{s_i, s_{i+1}, \cdots, s_j\}, \quad s_k \in S, k \in \{i, \cdots, j\} \quad (1)$$

However, experts may not express their opinions by using several linguistic labels. Because of this situation, context-free grammars $G_H = (V_N, V_T, I, P)$ are introduced to develop comparative linguistic expressions. An illustrative context free grammar for building such expressions can be provided as below.

$$V_N = \left\{ \begin{array}{l} \langle primary\ term \rangle, \langle composite\ term \rangle \\ \langle unary\ term \rangle, \langle binaryt\ erm \rangle, \langle conjunction \rangle \end{array} \right\},$$

$$V_T = \left\{ \begin{array}{l} lower\ than, greater\ than, at\ least, at\ most, \\ between, and, S_0, S_1, \ldots, S_t \end{array} \right\}$$

$I \in V_N,$

$P = \{I ::= \langle primaryterm \rangle \mid \langle compositeterm \rangle,$

$\langle compositeterm \rangle ::= \langle compositeterm \rangle$

$\langle primaryterm \rangle$

$\mid \langle binaryrelation \rangle \langle primaryterm \rangle$

$\mid \langle conjunction \rangle \langle primaryterm \rangle,$

$\langle primaryterm \rangle ::= S_0 \mid S_1 \mid \ldots \mid S_t,$

$\langle unaryrelation \rangle ::= lowerthan \mid greaterthan$

$\mid atleast \mid atmost,$

$\langle binaryrelation \rangle ::= between,$

$\langle conjunction \rangle ::= and\}.$

These expressions can be converted into hesitant linguistic fuzzy set with the help of the following transformation function.

Definition 2 [48]: Let $S = \{s_0, \cdots, s_\tau\}$ be a linguistic term set, the transformation function (E_{G_H}) converts the comparative linguistic expressions $ll \in S_{ll}$ generated by the context-free grammar (G_H) into hesitant linguistic fuzzy set (H_S). The details are demonstrated in the equation (2).

$$E_{G_H} : S_{ll} \rightarrow H_s \quad (2)$$

In this equation, S_{ll} represents the domain generated by the context-free grammar G_H. Additionally, the comparative linguistic expressions (ll) are modelled by fuzzy membership functions while calculating its correspondent fuzzy envelop [49]. Equation (3) gives information about this process.

$$F(H_s) = T(a, b, c, d) \quad (3)$$

Interval-valued intuitionistic fuzzy set identifies the membership and non-membership degrees of elements within the extreme values. Hence, it is obvious that more precise results can be achieved for the complex decision-making problems [50]. Intuitionistic fuzzy set I on U is indicated in the equation (4) [51].

$$I = \{\langle \vartheta, \mu_I(\vartheta), n_I(\vartheta) \rangle / \vartheta \epsilon U\} \quad (4)$$

In this equation, the $\mu_I(\vartheta) : U \rightarrow [0, 1]$ and $n_I(\vartheta) : U \rightarrow [0, 1]$ are the membership and non-membership degrees.

They can be defined as $0 \leq \mu_I(\vartheta) + n_I(\vartheta) \leq 1$. Additionally, $\mu_I(\vartheta)$ and $n_I(\vartheta)$ give information about the intervals which are the degrees of belongingness and non-belongingness of ϑ respectively. $\vartheta \epsilon U$ is for each interval, and $\mu_{IU}(\vartheta)$ is the upper and $\mu_{IL}(\vartheta)$ is the lower values of $\mu_I(\vartheta)$ while $n_{IU}(\vartheta)$ is the upper and $n_{IL}(\vartheta)$ is the lower values of $n_I(\vartheta)$. They can be shown in interval-valued intuitionistic sets as $\mu_{IL}(\vartheta), \mu_{IU}(\vartheta), n_{IL}(\vartheta), n_{IU}(\vartheta)$. Thus, intuitionistic fuzzy set I on U can be given as in the equations (5) and (6).

$$I = \{\vartheta, [\mu_{IL}(\vartheta), \mu_{IU}(\vartheta)], [n_{IL}(\vartheta), n_{IU}(\vartheta)] / \vartheta \epsilon U\} \quad (5)$$

$$0 \leq \mu_{IU}(\vartheta) + n_{IU}(\vartheta) \leq 1 \mu_{IL}(\vartheta) \geq 0, \quad n_{IL}(\vartheta) \geq 0 \quad (6)$$

Moreover, the unknown degree of an intuitionistic fuzzy interval of $\vartheta \epsilon U$ in I can be identified by considering the equation (7).

$$\tau_I(\vartheta) = 1 - \mu_I(\vartheta) - n_I(\vartheta) \quad (7)$$

On the other side, the elements of interval-valued intuitionistic fuzzy set (I) can be shown as in the equation (8)

$$I = ([a, b], [c, d]) \quad (8)$$

In this equation, a, b, c, d represent $\mu_{IL}(\vartheta), \mu_{IU}(\vartheta), n_{IL}(\vartheta), n_{IU}(\vartheta)$ respectively. In addition to them, an intuitionistic hesitant fuzzy set (H) can be defined as in the equations (9) and (10).

$$H = \{\langle \vartheta, h_1(\vartheta), h_2(\vartheta) \rangle, \vartheta \in U\} \quad (9)$$

$$\forall \mu \in h_1(\vartheta), n \in h_2(\vartheta) \quad (10)$$

Furthermore, IVIHF set ($\tilde{H}$) is given on the equation (11).

$$\tilde{H} = \{\langle \vartheta, h_H(\vartheta) \rangle, \vartheta \in U\} \quad (11)$$

B. IVIHF DEMATEL

DEMATEL approach is mainly considered to find the significant factors in decision making process. With the help of this analysis, the weights of the criteria can be identified. The main superiority of this methodology over the similar ones is that impact relation map can be made [52]. Owing to this situation, the causality relationship among the factors can be determined. Especially in recent years, this method is used with IVIHF sets. In the first stage, the linguistic choices can be provided related to the relationship between each criteria and dimensions. In this scope, equation (12) gives information about the linguistic evaluations in the form of interval-valued intuitionistic fuzzy numbers [53]. In this equation, a_{ij} and c_{ij} represent lower whereas b_{ij} and d_{ij} give information about the upper values of belongingness and non-belongingness degrees.

$$\tilde{Z}_{ij} = ([a_{ij}, b_{ij}], [c_{ij}, d_{ij}]) \quad (12)$$

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Additionally, the matrix is presented in the equation (13).

$$\tilde{Z} = \begin{bmatrix} 0 & \tilde{z}_{12} & \cdots & \cdots & \tilde{z}_{1n} \\ \tilde{z}_{21} & 0 & \cdots & \cdots & \tilde{z}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1} & \tilde{z}_{n2} & \cdots & \cdots & 0 \end{bmatrix} \quad (13)$$

The average values of decision makers' evaluations are considered as in the equation (14).

$$\tilde{Z} = \frac{\tilde{Z}^1 + \tilde{Z}^2 + \tilde{Z}^3 + \ldots \tilde{Z}^n}{n} \quad (14)$$

In the next step, normalization process is made by using the equations (15)-(17).

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \cdots & \tilde{x}_{nn} \end{bmatrix} \quad (15)$$

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{Z_{\acute{a}_{ij}}}{r}, \frac{Z_{\acute{b}_{ij}}}{r} \right), \left(\frac{Z_{\acute{c}_{ij}}}{r}, \frac{Z_{\acute{d}_{ij}}}{r} \right) \quad (16)$$

$$r = max \left(max_{1 \le i \le n} \sum_{j=1}^{n} Z_{\acute{b}_{ij}}, max_{1 \le i \le n} \sum_{j=1}^{n} Z_{\acute{b}_{ij}} \right) \quad (17)$$

The following includes the generation of the total relation matrix and the equations (18)-(22) are considered [54].

$$X_{\acute{a}} = \begin{bmatrix} 0 & a'_{12} & \cdots & \cdots & a'_{1n} \\ a'_{21} & 0 & \cdots & \cdots & a'_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a'_{n1} & a'_{n2} & \cdots & \cdots & 0 \end{bmatrix}, \ldots,$$

$$X_{\acute{d}} = \begin{bmatrix} 0 & d'_{12} & \cdots & \cdots & d'_{1n} \\ d'_{21} & 0 & \cdots & \cdots & d'_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ d'_{n1} & d'_{n2} & \cdots & \cdots & 0 \end{bmatrix} \quad (18)$$

$$\tilde{T} = \lim_{k \to \infty} \tilde{X} + \tilde{X}^2 + \ldots + \tilde{X}^k \quad (19)$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \cdots & \tilde{t}_{nn} \end{bmatrix} \quad (20)$$

$$\tilde{t}_{ij} = \left(\left(a''_{ij}, b''_{ij} \right), \left(c''_{ij}, d''_{ij} \right) \right) \quad (21)$$

$$\left[a''_{ij} \right] = X_{\acute{a}} \times (I - X_{\acute{a}})^{-1}, \ldots, \left[d''_{ij} \right] = X_{\acute{d}} \times (I - X_{\acute{d}})^{-1} \quad (22)$$

After that, the values of $\tilde{D}$ and $\tilde{R}_i$ are calculated with the help of the equations (23)-(24).

$$\tilde{D}_i = \left[\sum_{j=1}^{n} \tilde{t}_{ij} \right]_{n \times 1} \quad (23)$$

$$\tilde{R}_i = \left[\sum_{j=1}^{n} \tilde{t}_{ij} \right]'_{1 \times n} \quad (24)$$

In this process, $\left(\tilde{D}_i + \tilde{R}_i \right)$ is considered to calculate the weights of the criteria. On the other side, $\left(\tilde{D}_i - \tilde{R}_i \right)$ gives information about the influencing directions. Finally, accuracy function ($H(i)$) is considered to compute the weights of criteria as in the equation (25).

$$H(i) = \frac{a + b + c + d}{2} \quad (25)$$

C. IVIHF VIKOR

VIKOR is used to rank different items in complex decision-making process. The main advantage of this approach is that it is very easy to make calculation. On the other side, in the analysis process, maximum utility and minimum regret are considered [55]. Because of this situation, it is thought that more appropriate results can be reached. VIKOR method can also be proposed with interval-valued intuitionistic fuzzy sets [56]. In the first stage, the linguistic evaluations for the alternatives re obtained. These evaluations are converted to the interval-valued intuitionistic fuzzy numbers. After that, the fuzzy decision matrix (D) is generated with the help of the equations (26)-(27).

$$D = \begin{matrix} & \begin{matrix} C1 & C2 & C3 & \ldots & Cn \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} h_{11} & h_{12} & h_{13} & \cdots & h_{1n} \\ h_{21} & h_{22} & h_{23} & \cdots & h_{2n} \\ h_{31} & h_{32} & h_{33} & \cdots & h_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ h_{m1} & h_{m2} & h_{m3} & \cdots & h_{mn} \end{bmatrix} \end{matrix} \quad (26)$$

$$h_{ij} = \frac{1}{k} \left[\sum_{e=1}^{n} h^e_{ij} \right], \quad i = 1, 2, 3, \ldots, m \quad (27)$$

In the next stage, the best ($fj*$) and worst (f_J^-) values of decision matrix are calculated as in the equation (28).

$$f_J^* = max_i x_{ij} \text{ and } f_J^- = min_i x_{ij} \quad (28)$$

Just then, S_i, R_i and Q_i values are computed by the equations (29)-(31). In these equations, v represents the maximum group utility.

$$S_i = \sum_{i=1}^{n} w_j \frac{\left(\left| f_j^* - x_{ij} \right| \right)}{\left(\left| f_j^* - f_j^- \right| \right)} \quad (29)$$

$$R_i = max_j \left[w_j \frac{\left(\left| f_j^* - x_{ij} \right| \right)}{\left(\left| f_j^* - f_j^- \right| \right)} \right] \quad (30)$$

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TABLE 1. Proposed dimensions and criteria of electricity pricing.

Dimensions	Criteria	References
Economic and Political (Dimension 1)	Volatility in currency (criterion 1)	[14],[15]
	Inflation (criterion 2)	[17],[18]
	Industrial production (criterion 3)	[16],[19]
	Political factors (criterion 4)	[21],[22]
	Consumption habits (criterion 5)	[23]
Environmental and Technological (Dimension 2)	Supplier facilities (criterion 6)	[24],[25]
	Weather conditions (criterion 7)	[27],[28]
	Geographical conditions (criterion 8)	[28]
	Technological Improvement (criterion 9)	[29],[30]
	Environmental Awareness (criterion 10)	[32]

$$\tilde{Q}_i = \frac{v(S_i - S^*)}{(S^- - S^*)} + (1 - v)\frac{(R_i - R^*)}{(R^- - R^*)} \qquad (31)$$

In this framework, two conditions should be satisfied for the acceptable advantage and stability. To achieve this objective, equations (32) and (33) are considered.

$$Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) \geq \frac{1}{(j-1)} \qquad (32)$$

$$Q\left(A^{(M)}\right) - Q\left(A^{(1)}\right) < \frac{1}{(j-1)} \qquad (33)$$

In these equations, $A^{(1)}$ and $A^{(2)}$ give information about the best and the second ranking results. In the final stage, alternatives are ranked.

D. IVIHF TOPSIS

TOPSIS is also another popular MCDM technique to rank different alternatives. In this process, both positive and negative ideal solutions are considered. This model can also be extended based on interval-valued intuitionistic fuzzy sets [57]. In this process, the expert opinions are modified by considering these sets. For this purpose, equations (26) and (27) are used. After that, the positive and negative ideal solutions (A^+, A^-) are calculated by considering the equations (34) and (35). In these equations, v_{ij} represents the weight of decision matrix.

$$A^+ = \max(v_1, v_2, v_3, \dots v_n) \qquad (34)$$
$$A^- = \min(v_1, v_2, v_3, \dots v_n) \qquad (35)$$

Later, the closeness coefficient (CC_i) values are calculated by considering the equations (36)-(38) [58].

$$D_i^+ = \sqrt{\sum_{i=1}^{m}(v_i - A_i^+)^2} \qquad (36)$$

$$D_i^- = \sqrt{\sum_{i=1}^{m}(v_i - A_i^-)^2} \qquad (37)$$

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \qquad (38)$$

Alternatives with the highest CC_i value are at the top of the ranking.

TABLE 2. Linguistic terms for expert evaluations.

Linguistic Terms	Percentages
Very Low (VL)	0.1
Low (L)	0.2
Medium Low (ML)	0.3
Medium (M)	0.4
Medium High (MH)	0.5
High (H)	0.6
Very High (VH)	0.7
Absolute (A)	0.8

TABLE 3. IVIHF relation matrix.

Dimensions	D1	D2
D1	-	((0.70,0.60), (0.60,0.40))
D2	((0.40,0.70), (0.30,0.60))	-

TABLE 4. IVIHF normalized matrix.

Dimensions	D1	D2
D1	-	((1.00,0.86), (0.86,0.57))
D2	((0.57,1.00), (0.43,0.86))	-

TABLE 5. IVIHF Total Relation Matrix.

Dimensions	D1	D2
D1	((1.33,6.00), (0.58,0.96))	((2.33,6.00), (1.35,1.12))
D2	((1.33,7.00), (0.68,1.68))	((1.33,6.00), (0.58,0.96))

IV. ANALYSIS RESULTS

In this study, an integrated decision making model is applied for evaluating the alternatives. The proposed model is illustrated into three stages as seen in Figure 1.

The analysis of the study consists of three different stages. In the first part, the decision-making problem is defined, and the evaluations are collected properly. In the second stage, the dimensions and criteria are weighted with IVIHF DEMATEL. In the third stage, E7 economies are ranked with respect to the effectiveness of the management of electricity prices by using IVIHF VIKOR. Additionally, to check the consistency of the ranking results, another evaluation is also made by using IVIHF TOPSIS. On the other side, sensitivity analysis is performed to ten different cases consecutively to evaluate the coherency of the ranking results.

In this study, a new model is proposed to understand the factors that have an influence in electricity prices. The subject is quite important for the countries because electricity affects the social and economic development of the countries. In this context, the model to be created to determine electricity prices should be effective. Therefore, DEMATEL approach has been considered in determining the weights of the criteria.

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TABLE 6. Weights of Criteria and Dimensions for Electricity Pricing.

Dimensions	Weights	Criteria	Local Weights	Global Weights
Economic and Political (Dimension 1)	0.5	Volatility in Currency (criterion 1)	0.190	0.095
		Inflation (criterion 2)	0.215	0.107
		Industrial Production (criterion 3)	0.201	0.101
		Political Factors (criterion 4)	0.194	0.097
		Consumption Habits (criterion 5)	0.200	0.100
Environmental and Technological (Dimension 2)	0.5	Supplier Facilities (criterion 6)	0.185	0.093
		Weather Conditions (criterion 7)	0.205	0.103
		Geographical Conditions (criterion 8)	0.205	0.103
		Technological Improvement (criterion 9)	0.212	0.106
		Environmental Awareness (criterion 10)	0.192	0.096

TABLE 7. Defuzzified decision matrix.

Criteria	A1	A2	A3	A4	A5	A6	A7
C1	0.80	0.68	0.75	0.75	0.75	0.75	0.75
C2	0.80	0.80	0.50	0.80	0.68	0.80	0.63
C3	0.83	0.70	0.80	0.85	0.83	0.75	0.63
C4	0.75	0.75	0.80	0.77	0.75	0.78	0.68
C5	0.80	0.68	0.78	0.75	0.78	0.78	0.77
C6	0.80	0.70	0.75	0.80	0.80	0.63	0.80
C7	0.75	0.75	0.50	0.70	0.80	0.85	0.83
C8	0.85	0.68	0.85	0.68	0.78	0.80	0.68
C9	0.75	0.70	0.75	0.75	0.78	0.75	0.80
C10	0.83	0.63	0.78	0.83	0.80	0.75	0.80

TABLE 8. Ranking Results.

Alternatives	Si	Ri	Qi
A1 (China)	0.132	0.053	0.067
A2 (India)	0.688	0.106	0.991
A3 (Brazil)	0.394	0.107	0.735
A4 (Mexico)	0.304	0.103	0.616
A5 (Russia)	0.250	0.045	0.106
A6 (Indonesia)	0.320	0.093	0.550
A7 (Turkey)	0.442	0.101	0.725

TABLE 9. Comparative Ranking Results.

Alternatives	IVIHF VIKOR	IVIHF TOPSIS
A1 (China)	1	1
A2 (India)	7	7
A3 (Brazil)	6	5
A4 (Mexico)	4	4
A5 (Russia)	2	2
A6 (Indonesia)	3	3
A7 (Turkey)	5	6

This method is preferred because it has some advantages over other methods such as determining the causality relationship between criteria. In addition, in the ranking of E7 countries, analysis is made with both VIKOR and TOPSIS methods. Thus, it will be possible to measure the consistency of the results to be obtained. On the other hand, in this proposed model, a hybrid analysis is performed. In other words, different MCDM techniques have been considered both in

determining the criteria weights and ranking the countries. The most important advantage of the hybrid method is that objective results are obtained at every stage of the analysis [59], [60]. Furthermore, these methods are used with fuzzy logic to manage uncertainty in decision-making processes more effectively. However, over the years, more complex problems have arisen in decision-making processes. Therefore, new techniques are needed to solve these problems [61], [62]. In this context, in the model proposed in the study, interval-valued intuitionistic fuzzy numbers are taken into consideration instead of classical fuzzy numbers. These numbers can differentiate the positive and the negative indication for an element's interval membership and non-membership in the set [63], [64]. In this way, it is possible to reach more accurate and consistent results. In summary, the motivation of the study is to create a suitable model by analyzing electricity prices in emerging economies in a multidimensional way and to determine the factors that are effective in this process.

A. DEFINITION OF THE DECISION-MAKING PROBLEM
In order to understand which factors are more important for electricity prices, firstly, the criteria should be identified. For this purpose, the literature is reviewed in a detailed manner and 10 different criteria are determined. The details of these dimensions and criteria are demonstrated on Table 1.

Table 1 indicates that volatility in currency exchange rate is a significant indicator for electricity pricing. If the currency affects electricity prices, it is possible to understand that the country's energy needs are supplied from the outside. The increase in the exchange rate makes energy more expensive, as the externally supplied electrical energy is purchased in foreign currency. On the other hand, inflation rate can also have an impact on electricity prices Since this situation increases the price of the raw material from which electricity is produced, the high inflation rate causes an increase in electricity prices in the future. Moreover, industrial production can have a significant impact on electricity prices. In other words, if the industrial production of a country is increasing, the need for electricity will increase. Furthermore, policy makers in the country can have an impact

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TABLE 10. Ranking Results by the Cases.

Cases	Methodology	A1	A2	A3	A4	A5	A6	A7
Case 1	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	5	4	2	3	6
Case 2	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	5	4	2	3	6
Case 3	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	6	4	2	3	5
Case 4	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	5	4	2	3	6
Case 5	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	6	4	2	3	5
Case 6	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	5	4	2	3	6
Case 7	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	5	4	2	3	6
Case 8	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	5	4	2	3	6
Case 9	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	5	4	2	3	6
Case 10	IVIHF VIKOR	1	7	6	4	2	3	5
	IVIHF TOPSIS	1	7	5	4	2	3	6

on electricity prices through their strategies. In addition, people's consumption habits can cause electricity prices to change.

Additionally, the number of electricity suppliers can have an impact on electricity prices. Also, changes in the weather can affect electricity prices. For example, in a situation where the weather is extremely cold, the demand for electricity will increase and this will cause the prices to go up. Similarly, the geographical features of the country may have an important role on electricity prices. Within this context, in a situation where the country is very mountainous, it is not very easy to supply electrical energy which leads to rising prices. On the other hand, thanks to technological developments, it is possible to cost less in electricity. Finally, in the environmental sensitivity criterion, awareness of the public towards electricity consumption is taken into consideration. For example, if the public is not sensitive to energy consumption, it will consume more energy than necessary and cause the demand to increase unnecessarily. After defining these dimensions and criteria, the evaluations of decision makers are provided. In this context, 3 decision makers made evaluations about these factors. These people have at least 20-year experience in this area. This expert team consists of academicians and decision makers. In this evaluation, linguistic terms are considered. Table 2 gives information about the details of these terms.

The evaluations of the experts regarding the dimension and criteria are given on the Appendix part (Table 11-13). After that, IVIHF relation matrix is created which is given on Table 3.

After that, this matrix is normalized, and the details are given on Table 4.

Just then, total relation matrix is created as in Table 5.

B. EVALUATION OF THE DIMENSIONS AND CRITERIA

In the second stage, the weights of the dimensions and criteria are calculated. Table 6 indicates the details of these results.

Table 6 shows that both dimensions (economic & political and environmental & technological) have the equal importance. Moreover, it is also identified that inflation (criterion 2) has the highest weight (0.107). Similarly, it is also determined that technological improvement (criterion 9) is also another important variable that affects electricity prices. Nevertheless, volatility in currency (criterion 1), political factors (criterion 4), supplier facilities (criterion 6) and environmental awareness (criterion 10) are least significant items for this situation.

C. RANKING E7 ECONOMIES

In the final stage of the analysis, the performance of emerging economies regarding the electricity pricing is evaluated. Firstly, the decision makers made their evaluations regarding the alternative countries. The details are demonstrated on Table 14. After that, the decision matrix is created. The details of this matrix are given on Table 15. In the next stage, the defuzzified decision matrix is generated. Table 7 includes the details of this matrix.

In the final stage, E7 economies are ranked. The analysis results are illustrated on Table 8.

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TABLE 11. Linguistic Choices of Decision Makers for Dimensions.

	D1			D2		
	DM1	DM2	DM3	DM1	DM2	DM3
D1	- - - -	- - - -	- - - -	VH H H M	VH H H M	VH H H M
D2	M VH ML H	M VH ML H	M VH ML H	- - - -	- - - -	- - - -

TABLE 12. Linguistic Choices of Decision Makers for Criteria of Dimension 1.

	C1			C2			C3		
	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
C1	- - - -	- - - -	- - - -	M H VL ML	M MH L ML	M MH L ML	M H VL ML	ML MH L M	M H VH VL L
C2	VH H ML ML	VH H ML ML	VH H ML ML	- - - -	- - - -	- - - -	M VH L ML	H VH VL L	H VH VL L
C3	L MH ML M	VL ML VL L	VL ML VL L	M MH L ML	M MH L ML	M MH L ML	- - - -	- - - -	- - - -
C4	VL ML VL L	VL ML VL L	VL ML VL L	L MH L ML	L MH ML M	VL ML VL L	H VH VL L	H VH VL L	H VH VL L
C5	L MH MH L	M L MH MH L	M L MH MH L	M VH L ML	M VH L ML	M VH L ML	M H VL ML	ML MH L M	M MH H VL ML

	C4			C5		
	DM1	DM2	DM3	DM1	DM2	DM3
C1	H VH VL L	H VH VL L	H VH VL L	VH VL L L	M MH VL ML	M MH VL ML
C2	H VH VL L	MH H VL L	H VH VL L	H VH VL L	MH H VL L	M MH VL ML
C3	L MH ML M	L MH ML M	L MH ML M	L MH ML M	L MH ML M	L MH ML M
C4	- - - -	- - - -	- - - -	MH H VL L	M H VL L	MH H VL L
C5	ML MH L M	ML MH L M	ML MH L M	- - - -	- - - -	- - - -

TABLE 13. Linguistic Choices of Decision Makers for Criteria of Dimension 2.

	C1			C2			C3		
	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
C1	- - - -	- - - -	- - - -	ML MH L ML	ML MH L ML	ML MH L ML	M H VL ML	ML MH L M	M H VL ML
C2	M H VL ML	M VH L ML	M VH L ML	- - - -	- - - -	- - - -	M MH L ML	M MH L ML	M MH L ML
C3	L MH L ML	L MH L ML	L MH L ML	M MH L ML	M MH L ML	M MH L ML	- - - -	- - - -	- - - -
C4	M MH L ML	M MH L ML	M MH L ML	M VH L ML	ML MH M MH	M VH L ML	H VH VL L	H VH VL L	H VH VL L
C5	L MH ML M	L MH ML M	L MH ML M	M VH L ML	ML MH M MH	M VH L ML	M H VL ML	ML MH L M	M H VL ML

	C4			C5		
	DM1	DM2	DM3	DM1	DM2	DM3
C1	M H VL ML	M H VL ML	M H VL ML	VH VL L L	VH VL L L	VH VL L L
C2	M H VL ML	M H VL ML	M H VL ML	MH H VL L	M H VL ML	MH H VL L
C3	M H VL ML	H VH VL L	M H VL ML	MH H VL L	MH H VL L	MH H VL L
C4	- - - -	- - - -	- - - -	M H VL ML	M H VL ML	M H VL ML
C5	ML MH L M	ML MH L M	ML MH L M	- - - -	- - - -	- - - -

Table 8 gives information that China is the best country with respect to the management of electricity prices because it has the lowest Q_i value. Similarly, Russia has also second-best performance regarding this situation. On the other side, Turkey, Brazil, and India have the lowest performance in comparison with others. In addition to this issue, an evaluation has also been performed by IVIHF TOPSIS methodology to make comparative analysis. The details are indicated on Table 9.

Table 9 indicates that the results of IVIHF VIKOR and IVIHF TOPSIS are quite similar. This situation gives information that ranking results in this study are consistent. On the

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TABLE 14. Linguistic Choices of Decision Makers for Alternatives.

Alternative 1 (China)

	DM1				DM2				DM3			
C1	ML	MH	ML	M	H	A	VL	L	H	A	VL	L
C2	H	A	VL	L	ML	MH	ML	M	ML	H	ML	M
C3	H	A	VL	L	ML	H	ML	M	ML	H	ML	M
C4	ML	MH	ML	M	ML	MH	ML	M	MH	VH	VL	L
C5	H	A	VL	L	MH	VH	VL	L	H	A	VL	L
C6	ML	H	ML	M	ML	H	ML	M	ML	H	ML	M
C7	MH	VH	VL	L	ML	VH	L	L	MH	VH	VL	L
C8	H	A	VL	L	H	A	VL	L	H	A	VL	L
C9	ML	MH	ML	M	ML	VH	L	L	ML	MH	ML	M
C10	H	A	VL	L	H	A	VL	L	ML	H	ML	M

Alternative 2 (India)

	DM1				DM2				DM3			
C1	VL	M	L	ML	H	A	VL	L	VL	M	L	ML
C2	H	A	VL	L	ML	MH	ML	M	H	A	VL	L
C3	VL	M	L	ML	H	A	VL	L	ML	MH	ML	M
C4	ML	MH	ML	M	ML	MH	ML	M	ML	MH	ML	M
C5	H	A	VL	L	VL	M	L	ML	H	A	VL	L
C6	MH	VH	VL	L	VL	M	L	ML	H	A	VL	L
C7	MH	VH	VL	L	VL	M	L	ML	MH	VH	VL	L
C8	VL	M	L	ML	VL	M	L	ML	H	A	VL	L
C9	MH	VH	VL	L	VL	M	L	ML	H	A	VL	L
C10	VL	M	L	ML	ML	MH	ML	M	ML	MH	ML	M

Alternative 3 (Brazil)

	DM1				DM2				DM3			
C1	MH	VH	VL	L	MH	VH	VL	L	MH	VH	VL	L
C2	VL	M	L	ML	VL	M	L	ML	VL	M	L	ML
C3	ML	VH	L	L	ML	H	ML	M	MH	A	VL	L
C4	MH	A	VL	L	MH	VH	VL	L	MH	VH	VL	L
C5	ML	H	ML	M	ML	MH	ML	M	ML	MH	ML	M
C6	MH	VH	VL	L	MH	VH	VL	L	MH	VH	VL	L
C7	VL	M	L	ML	VL	M	L	ML	MH	VL	M	L
C8	H	A	VL	L	H	A	VL	L	H	A	VL	L
C9	ML	MH	ML	M	ML	MH	ML	M	ML	MH	ML	M
C10	ML	MH	ML	M	ML	H	ML	M	ML	H	ML	M

Alternative 4 (Mexico)

	DM1				DM2				DM3			
C1	ML	MH	ML	M	ML	VH	L	L	MH	VH	VL	L
C2	ML	H	ML	M	H	A	VL	L	MH	VH	VL	L
C3	H	A	VL	L	H	A	VL	L	H	A	VL	L
C4	ML	MH	ML	M	ML	VH	L	L	ML	H	ML	M
C5	ML	VH	L	L	ML	MH	ML	M	ML	MH	ML	M
C6	ML	MH	ML	M	H	A	VL	L	H	A	VL	L
C7	VL	M	L	ML	H	A	VL	L	ML	MH	ML	M
C8	H	A	VL	L	H	A	VL	L	VL	M	L	ML
C9	ML	MH	ML	M	ML	VH	L	L	ML	MH	VH	VL
C10	ML	H	ML	M	H	A	VL	L	H	A	VL	L

Alternative 5 (Russia)

	DM1				DM2				DM3			
C1	ML	MH	ML	M	ML	MH	ML	M	H	A	VL	L
C2	VL	M	L	ML	VL	M	L	ML	MH	A	VL	L
C3	H	A	VL	L	H	A	VL	L	ML	H	ML	M
C4	ML	MH	ML	M	ML	MH	ML	M	MH	VH	VL	L
C5	ML	H	ML	M	ML	H	ML	M	MH	VH	VL	L
C6	ML	MH	ML	M	H	A	VL	L	H	A	VL	L
C7	ML	MH	ML	M	H	A	VL	L	H	A	VL	L
C8	ML	H	ML	M	MH	VH	VL	L	MH	VH	VL	L
C9	MH	VH	VL	L	ML	H	ML	M	ML	H	ML	M
C10	ML	MH	ML	M	H	A	VL	L	H	A	VL	L

Alternative 6 (Indonesia)

	DM1				DM2				DM3			
C1	ML	VH	L	L	MH	VH	VL	L	MH	VH	VL	L
C2	ML	H	ML	M	ML	H	ML	M	ML	H	ML	M
C3	ML	MH	ML	M	ML	MH	ML	M	ML	MH	ML	M
C4	H	A	VL	L	ML	VH	L	L	MH	VH	VL	L
C5	MH	VH	VL	L	ML	VH	L	L	MH	A	VL	L
C6	VL	M	L	ML	MH	VH	VL	L	MH	VH	VL	L
C7	H	A	VL	L	H	A	VL	L	H	A	VL	L
C8	H	A	VL	L	ML	MH	ML	M	ML	MH	ML	M
C9	ML	VH	L	L	ML	VH	L	L	ML	VH	L	ML
C10	ML	VH	L	L	ML	VH	L	L	ML	VH	L	ML

Alternative 7 (Turkey)

	DM1				DM2				DM3			
C1	ML	VH	L	ML	ML	VH	L	ML	MH	VH	VL	L
C2	ML	MH	ML	M	ML	MH	ML	M	VL	M	L	ML
C3	VL	M	L	ML	VL	M	L	ML	ML	MH	L	ML
C4	VL	M	L	ML	VL	M	L	ML	MH	A	VL	L
C5	ML	VH	L	ML	MH	VH	VL	L	ML	H	ML	M
C6	H	A	VL	L	ML	H	ML	M	ML	VH	L	ML
C7	ML	H	ML	M	H	A	VL	L	H	A	VL	L
C8	MH	VH	VL	L	VL	M	L	ML	ML	H	ML	M
C9	MH	VH	VL	L	H	A	VL	L	H	A	VL	L
C10	MH	VH	VL	L	H	A	VL	L	H	A	VL	L

other side, the sensitivity analysis has been implemented to ten different cases consecutively to check the coherency of the analysis results [65]. These results are demonstrated on Table 10.

Table 10 shows that the ranking results are almost the same for each case. This issue gives information that the results are coherent in case of any possible changes in the weights of the criteria.

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TABLE 15. Interval-valued intuitionistic fuzzy decision matrix.

	A1	A2	A3	A4	A5	A6	A7
C1	((0.45,0.65),(0.20,0.30))	((0.35,0.60),(0.15,0.25))	((0.50,0.70),(0.10,0.20))	((0.37,0.63),(0.20,0.30))	((0.30,0.60),(0.25,0.35))	((0.30,0.60),(0.30,0.40))	((0.40,0.60),(0.20,0.30))
C2	((0.45,0.65),(0.20,0.30))	((0.45,0.65),(0.20,0.30))	((0.10,0.40),(0.20,0.30))	((0.47,0.70),(0.17,0.27))	((0.35,0.60),(0.15,0.25))	((0.30,0.60),(0.30,0.40))	((0.20,0.45),(0.25,0.35))
C3	((0.45,0.65),(0.20,0.30))	((0.33,0.57),(0.20,0.30))	((0.40,0.70),(0.20,0.30))	((0.60,0.80),(0.10,0.20))	((0.45,0.65),(0.20,0.30))	((0.30,0.60),(0.30,0.40))	((0.20,0.55),(0.20,0.30))
C4	((0.40,0.60),(0.20,0.30))	((0.30,0.60),(0.30,0.40))	((0.55,0.75),(0.10,0.20))	((0.30,0.60),(0.30,0.40))	((0.40,0.60),(0.20,0.30))	((0.47,0.73),(0.13,0.23))	((0.35,0.60),(0.15,0.25))
C5	((0.55,0.75),(0.10,0.20))	((0.35,0.60),(0.15,0.25))	((0.30,0.60),(0.30,0.40))	((0.30,0.60),(0.30,0.40))	((0.40,0.60),(0.20,0.30))	((0.47,0.73),(0.13,0.23))	((0.37,0.63),(0.20,0.30))
C6	((0.30,0.60),(0.30,0.40))	((0.40,0.65),(0.23,0.33))	((0.50,0.70),(0.10,0.20))	((0.45,0.65),(0.20,0.30))	((0.45,0.65),(0.20,0.30))	((0.30,0.53),(0.20,0.30))	((0.40,0.60),(0.20,0.30))
C7	((0.40,0.70),(0.15,0.25))	((0.30,0.60),(0.30,0.40))	((0.10,0.40),(0.20,0.30))	((0.33,0.57),(0.20,0.30))	((0.45,0.65),(0.20,0.30))	((0.60,0.80),(0.10,0.20))	((0.45,0.65),(0.20,0.30))
C8	((0.60,0.80),(0.10,0.20))	((0.35,0.60),(0.15,0.25))	((0.60,0.80),(0.10,0.20))	((0.35,0.60),(0.15,0.25))	((0.40,0.60),(0.20,0.30))	((0.45,0.65),(0.20,0.30))	((0.30,0.57),(0.20,0.30))
C9	((0.30,0.60),(0.25,0.35))	((0.40,0.60),(0.20,0.30))	((0.30,0.60),(0.25,0.35))	((0.37,0.63),(0.20,0.30))	((0.40,0.60),(0.20,0.30))	((0.30,0.60),(0.25,0.35))	((0.55,0.75),(0.10,0.20))
C10	((0.45,0.65),(0.20,0.30))	((0.20,0.45),(0.25,0.35))	((0.30,0.60),(0.25,0.35))	((0.45,0.65),(0.20,0.30))	((0.45,0.65),(0.20,0.30))	((0.30,0.60),(0.25,0.35))	((0.55,0.75),(0.10,0.20))

V. CONCLUSION

In this study, it is aimed to find the factors that affect the changes in the prices of electricity. In this framework, first, by reviewing the existing literature, 10 factors that may affect electricity prices are defined in two different dimensions. Then, the weights of these 10 factors are determined by using IVIHF DEMATEL method. In addition to this, E7 countries are ranked by using the IVIHF VIKOR approach. It is identified that the results of IVIHF VIKOR and IVIHF TOPSIS are quite similar. Additionally, a comparative evaluation is also made by using IVIHF TOPSIS methodology to check the consistency of the analysis results. On the other side, a sensitivity analysis has also been performed to ten different cases consecutively. It is defined that the ranking results are coherent based on the changes in the weights of the criteria. It is concluded that the inflation is the most important factor that affects electricity prices. Moreover, the technological improvement is the second most significant factor that affects electricity prices. Additionally, it is also identified that China (A1) is the number one country who meets the needs to keep electricity prices more stable. Furthermore, Russia (A5), is the second country in this regard. With its huge energy reserves such as natural gas, it succeeds in prevent its electricity prices to be volatilized. In the other hand, it is seen that energy-dependent countries such as India (A2) and Turkey (A7) take place on the last orders in the ranking.

VI. LIMITATIONS AND IMPLICATIONS

The most important point in this study is that inflation has caused a very effective increase in electricity prices. In this case, the main strategy should be following inflation expectations and take precautions in possible inflation changes. Taking measures such as reducing foreign dependency in energy, promoting export-oriented and imported substitute production, increasing the diversity of financial resources, and promoting savings in middle and high-income groups may also help to keep electricity prices low. Lots of the studies in the literature highlighted the importance of the similar results. As an example, Gonzalez *et al.* [17] studied this situation by considering cost criteria from a life-cycle perspective. They concluded that an increase in prices of inputs that are used in electricity generation pave the way for increase in electricity prices because it becomes more costly than before. When they tested their model in a sample township in central Catalonia, they found that in that area using renewable energy sources is more cost friendly. Thus, to prevent volatility in electricity prices, they recommended transmitting to renewable energy sources. In the other hand, Haratian *et al.* [18] evaluated other cost-effective options in Iran by examining off-grid renewable energy sources and identified that inflation rate and cost of energy generation are directly proportional. Hence, an increase in inflation rate causes an increase in cost of electricity production. In the long run, this also means an increase for electricity prices.

Additionally, it is also defined that technological improvement significantly affects electricity prices. With these improvements, it is possible to generate electricity with lower cost. For example, electricity generation can become cheaper owing to current developments such as hydrogen, carbon capture, and other types of renewable energy. The most important thing to ensure technological improvement is to give importance to companies' research and departments. In this context, it is very significant to follow the current developments in detail. If these developments cannot be followed effectively, electricity prices will be unnecessarily high, and as a result, the industry and economy of the country will be negatively affected. These results were also supported by various studies in the literature. For instance, Deng *et al.* [29] examined the seven regions in China by using data between 1997 and 2013. With establishing a cost function model, they

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studied the effect of technological improvement and price changes on inputs of electricity generation. It is identified that technological can lead a decrease in electricity prices. Mai *et al.* [30] also reached a conclusion that technological improvements reduce carbon dioxide emission cost, improve renewable energy generation and natural gas energy generation productivity.

The main limitation of this study is that only non-numeric data is taken into consideration. Thus, the future studies can focus on other data alternatives, such as numerical data. Evaluating the numerical data in these factors can also provide coherent results to minimize volatility in electricity prices. In the other hand, another important limitation of this study is the model that is used in the analysis process. Even though using fuzzy sets can help to reach a more comprehensive conclusion, by applying economical models, pinpoint results and net coefficients can be achieved. In addition to this, in this study only E7 countries are examined that can be accepted as a limitation. This evaluation can also be used for another country groups such as G7, BRICS, MINT, EU countries. In this way, a comparative analysis can be made, and new strategies can be created to manage volatility in electricity prices.

APPENDIX

See Table 11–15.

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