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An ExpTODIM-EDAS Based Multiple Attribute Group Decision-Making Framework for Supervision Effectiveness Evaluation of Small and Medium Sized Financial Institutions in Rural Areas under Intuitionistic Fuzzy Circumstances

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ABSTRACT: The supervision effectiveness evaluation of small and medium sized (SMS) financial institutions in rural areas is a multiple attribute group decision making (MAGDM). Recently, Recently, the Exponential TODIM (ExpTODIM) and Evaluation Based on Distance from Average Solution (EDAS) technique has been employed to manage MAGDM issues. The intuitionistic fuzzy sets (IFSs) are employed as a tool for portraying uncertain information during the supervision effectiveness evaluation of SMS financial institutions in rural areas. In this work, the intuitionistic fuzzy number (IFN) Exponential TODIM-EDAS (IFN-ExpTODIM-EDAS) technique is cultivated to manage the MAGDM under IFSs. Finally, a numerical case study for supervision effectiveness evaluation of SMS financial institutions in rural areas is constructed to verify the IFN-ExpTODIM-EDAS technique. The main novelties of this work are managed: (1) the ExpTODIM and EDAS technique was extended to IFSs; (2) Information Entropy is employed to manage weight values under IFSs. (3) the IFN-ExpTODIM-EDAS technique is founded to manage the MAGDM under IFSs; (4) a numerical example for supervision effectiveness evaluation of SMS financial institutions in rural areas; (5) some comparative analysis is employed to verify the IFN-ExpTODIM-EDAS technique.

INDEX TERMS: Multiple attribute group decision making (MAGDM) issue; intuitionistic fuzzy sets (IFSs); ExpTODIM technique; EDAS technique; supervision effectiveness evaluation

1. Introduction

Rural small and medium-sized financial institutions have scattered customers, small loan limits, high operating costs, high business risks, and relatively low returns. In terms of business operations, the agricultural product market has not yet been fully liberalized, and the rural economy is not a complete market economy[1, 2]. The scissor gap in agricultural products is widespread, and financial institutions also face difficulties in operating completely according to marketization. In terms of risk transfer mechanism, the current guarantee mechanism in rural areas is not sound, the application of agricultural insurance is not widespread, and farmers lack effective collateral, making it difficult to effectively transfer risks. In terms of credit environment, the current rural credit construction is lagging behind, the credit reporting system is not yet developed, and debt evasion and abandonment often occur. At the end of 2008, the non-performing loan ratio of agricultural loans in banking and financial institutions nationwide was nearly three times its average non-performing loan ratio[3, 4]. Rural small and medium-sized financial institutions are the main providers of rural credit, with agricultural loans accounting for nearly 70% of the loan balance[5]. When regulating them, it is necessary to consider their social responsibility, and then fully consider the relationship between their relevant indicator increment and stock, dynamic and static, commercial financing and policy financing, and so on[6, 7]. China is a developing country, and the imbalance in economic development and the backwardness of some regions have led to varying degrees of difficulties for rural small and medium-sized financial institutions located in underdeveloped and remote areas. Most of the existing rural small and medium-sized financial institutions have evolved from rural cooperative financial institutions and have gone through more than 50 years of development[8, 9]. Their management system has undergone multiple major adjustments, and the management system, property rights model, and equity structure are relatively complex. Many rural cooperative financial institutions have low operating levels, chaotic management, poor environment, high costs, and bear the transformation costs of "separation of banks and cooperatives" and handling rural cooperative foundations[10, 11]. These factors have caemployed rural small and medium-sized financial institutions to accumulate a large amount of non-performing assets. So far, there are still many rural small and medium-sized financial institutions in counties (cities) with double-digit non-performing assets, some even exceeding 40%[12, 13]. According to statistics, rural cooperative financial institutions with negative capital still account for a considerable proportion in various provinces, cities, and autonomous regions. These situations have resulted in a significant gap between the main regulatory indicators of rural small and medium-sized financial institutions, such as capital adequacy ratio, provision coverage rate, and loan concentration, and have increased the difficulty of supervision[14-16].

In previous years, many large state-owned banks and joint-stock commercial banks implemented flat management and strategic transfer, leading to a continuous contraction of rural branches, increased loan authority, and constraints on the financial development of counties, resulting in a widening deposit gap[17-19]. Rural small and medium-sized financial institutions are the main ones located in counties that provide financial services to farmers. In addressing the issues of "agriculture, rural areas, and farmers" and the lack of funds in the county economy, rural small and

medium-sized financial institutions bear the heavy responsibility of providing necessary financial support for agricultural production increase, farmers' income increase, and rural economic development[20-23]. They can be described as "supporting agriculture, rural areas, and farmers" and bear an unbearable burden, which can be said to be a significant responsibility. Therefore, when regulating rural small and medium-sized financial institutions, full consideration should be given to their historical status and social responsibility[24-28]. Establishing a modern financial enterprise system to ensure its sustainable development is the ultimate goal of the reform of rural small and medium-sized financial institutions [29-31]. The new round of reform of rural credit cooperatives, which began in 2003, focuses on improving the corporate governance structure through the reform of the property rights decision system of rural credit cooperatives. In terms of property rights reform, quite a few have transformed the original property rights system of rural credit cooperatives into a joint-stock cooperative system, or transformed into rural cooperative banks, or retained the name of rural credit cooperatives. Although the stock cooperative system has made progress and improvements compared to the cooperative system, this property rights model is still not conducive to establishing a corporate governance structure that conforms to the modern financial enterprise system[32-34]. The transformation of shareholding system is the core of improving the corporate governance structure of rural small and medium-sized financial institutions. Based on the current situation of rural small and medium-sized financial institutions in terms of property rights and corporate governance, it is determined that the reform of rural small and medium-sized financial institutions is a process of gradual promotion and continuous improvement[35-38]. How to promote the continuous reform of rural small and medium-sized financial institutions and ultimately establish a modern financial enterprise system is also an important part of the supervision work of rural small and medium-sized financial institutions.

Decision making is a conscious and selective behavior of humans, which is generally used to achieve certain goals[39-44]. Essentially, decision-making is the use of known decision information, followed by sorting various alternative solutions through a certain method, and selecting the best overall performance alternative solution to approach the decision-maker's expectations as closely as possible [45-49]. In daily life, decisions are closely related to us, and we must make decisions about food, clothing, housing, and transportation[50-53]. When it comes to purchasing a house, people often consider its price, surrounding environment, whether it is a school district house, transportation, medical care, commercial supporting facilities, and other attributes[54-56]. The price attribute of a house conflicts with the surrounding environment and transportation attributes. For example, it is almost unrealistic to buy a house with a good surrounding environment, convenient transportation, and low price. And the medical attributes and commercial supporting facilities attributes are partially interrelated, and often areas with more complete commercial supporting facilities also have more developed medical services. Therefore, people need to make decisions to choose the most suitable (cost-effective) house under allowable economic conditions. The discussion of classic multi-attribute decision-making problems has achieved many research results[57-61]. In many fields such as economic management, military engineering, emergency decision-making, etc., the theory and methods of MADM have shown its charm in solving practical problems and making reasonable decisions[62-65]. However, the

theoretical methods and practical applications of MADM research are still not perfect, and further in-depth research is needed[66-71]. The supervision effectiveness evaluation of SMS financial institutions in rural areas is MAGDM. The IFSs [72-75] are employed as a tool for portraying uncertain information during the supervision effectiveness evaluation of SMS financial institutions in rural areas. Furthermore, many decision algorithms use ExpTODIM [76, 77] and EDAS technique [78] separately to manage the MAGDM. Until now, no or few research algorithms have been investigated on entropy and ExpTODIM-EDAS technique under IFSs. Therefore, an combined intuitionistic fuzzy ExpTODIM-EDAS (IFN-ExpTODIM-EDAS) technique is constructed to manage MAGDM. An illustrative example for supervision effectiveness evaluation of SMS financial institutions in rural areas and some comparative analysis is constructed to verify the validity and reliability of IFN-ExpTODIM-EDAS technique. The main research goal and motivation of this paper is managed: (1) the ExpTODIM and EDAS technique was extended to IFSs; (2) Information Entropy technique is employed to manage weight under IFSs. (3) the IFN-ExpTODIM-EDAS technique is constructed to manage the MAGDM with IFSs; (4) a numerical example for supervision effectiveness evaluation of SMS financial institutions in rural areas; (5) some comparative analysis is constructed to verify the proposed technique.

The structure framework of this paper is managed below. In Sect. 2, the IFSs is managed. In Sect. 3, IFN-ExpTODIM-EDAS technique is managed with entropy technique. Sect. 4 manages an illustrative example for supervision effectiveness evaluation of SMS financial institutions in rural areas and some comparative analysis. Some remarks are constructed in Sect. 5.

2. Preliminaries

Atanassov [79] constructed the IFSs.

Definition 1[79]. The IFSs on Θ is managed:

$$F=\left\{\left\langle \theta,u_F\left(\theta\right),v_F\left(\theta\right)\right\rangle \middle| \theta\in\Theta\right\} \quad (1)$$

where $\mu_F\left(\theta\right)\in\left[0,1\right]$ is membership and $v_F\left(\theta\right)\in\left[0,1\right]$ is non-membership with information condition: $0\le\mu_F\left(\theta\right)+v_F\left(\theta\right)\le1$, $\forall\,\theta\in\Theta$. Then, $f\theta=\left(fu,fv\right)$ is denoted as an IFN.

Definition 2[80, 81]. Let $f\theta_1=\left(fu_1,fv_1\right)$ and $f\theta_2=\left(fu_2,fv_2\right)$, the score functions (SF) & accuracy functions (AF) of $f\theta_1$ and $f\theta_2$ is constructed:

$$SF\left(f\theta_1\right)=fu_1-fv_1, SF\left(f\theta_2\right)=fu_2-fv_2 \quad (2)$$

$$AF\left(f\theta_1\right)=fu_1+fv_1, AF\left(f\theta_2\right)=fu_2+fv_2 \quad (3)$$

For two IFNs $f\theta_1=\left(fu_1,fv_1\right)$ and $f\theta_2=\left(fu_2,fv_2\right)$, then[82]

(1) *if* $SF\left(f\theta_1\right)<SF\left(f\theta_2\right)$, $f\theta_1<f\theta_2$;
(2) *if* $SF\left(f\theta_1\right)=SF\left(f\theta_2\right)$,
$AF\left(f\theta_1\right)<AF\left(f\theta_2\right)$, $f\theta_1<f\theta_2$;
(3) *if* $SF\left(f\theta_1\right)=SF\left(f\theta_2\right)$,
$AF\left(f\theta_1\right)=AF\left(f\theta_2\right)$, $f\theta_1=f\theta_2$.

Definition 3[83]. Let t $f\theta_1=\left(fu_1,fv_1\right)$ and $f\theta_2=\left(fu_2,fv_2\right)$ be IFNs, the IFN distanced measure (IFNDM) is constructed:

$$IFNDM\left(d\theta_1, d\theta_2\right)=\frac{1}{2}\left[\left|\frac{2\left(fu_1 f\pi_2-fu_2 f\pi_1-4\left(fu_1-fu_2\right)\right)}{4-f\pi_1 f\pi_2}\right|+\left|\frac{4\left(fv_1-fv_2\right)+2\left(fv_1 f\pi_2-fv_2 f\pi_1+2\left(f\pi_1-f\pi_2\right)\right)}{4-f\pi_1 f\pi_2}\right|\right] \quad (4)$$

where $f\pi_1=1-fu_1-fv_1, f\pi_2=1-fu_2-fv_2.$

Definition 4[82]. Let t $f\theta_1=\left(fu_1, fv_1\right)$ and $f\theta_2=\left(fu_2, fv_2\right)$, the operation is constructed:

$$f\theta_1\oplus f\theta_2=\left(fu_1+fu_2-fu_1fu_2, fv_1fv_2\right) \quad (5)$$

$$f\theta_1\otimes f\theta_2=\left(fu_1fu_2, fv_1+fv_2-fv_1fv_2\right) \quad (6)$$

$$\xi f\theta_1=\left(1-\left(1-fu_1\right)^{\xi},\left(fv_1\right)^{\xi}\right), \xi>0 \quad (7)$$

$$\left(f\theta_1\right)^{\xi}=\left(\left(fu_1\right)^{\xi}, 1-\left(1-fv_1\right)^{\xi}\right), \xi>0 \quad (8)$$

From Definition 2, the operation laws are constructed.

(1) $f\theta_1\oplus f\theta_2=f\theta_2\oplus f\theta_1, f\theta_1\otimes f\theta_2=f\theta_2\otimes f\theta_1,\left(\left(f\theta_1\right)^{\xi_1}\right)^{\xi_2}=\left(f\theta_1\right)^{\xi_1\xi_2}$;

(2) $\xi\left(f\theta_1\oplus f\theta_2\right)=\xi f\theta_1\oplus\xi f\theta_2,\left(f\theta_1\otimes f\theta_2\right)^{\xi}=\left(f\theta_1\right)^{\xi}\otimes\left(f\theta_2\right)^{\xi}$;

(3) $\xi_1 f\theta_1\oplus\xi_2 f\theta_1=\left(\xi_1+\xi_2\right)f\theta_1,\left(f\theta_1\right)^{\xi_1}\otimes\left(f\theta_1\right)^{\xi_2}=\left(f\theta_1\right)^{\left(\xi_1+\xi_2\right)}$.

The IFWA and IFWG technique is introduced.

Definition 5[84]. Let $f\theta_j=\left(fu_j, fv_j\right)$ be a family of IFNs, the IFWA technique is:

$$\begin{aligned} &IFWA_{fw}\left(f\theta_1, f\theta_2,\ldots, f\theta_n\right)\\ &=\bigoplus_{j=1}^{n}\left(fw_j f\theta_j\right)\\ &=\left(1-\prod_{j=1}^{n}\left(1-fu_j\right)^{fw_j},\prod_{j=1}^{n}\left(fv_j\right)^{fw_j}\right)\end{aligned} \quad (9)$$

where $fw=\left(fw_1, fw_2,..., fw_n\right)^T$ be weight values of $f\theta_j,\ fw_j>0,\sum_{j=1}^{n}fw_j=1.$

Definition 6[85]. Let $f\theta_j=\left(fu_j, fv_j\right)$ be a family of IFNs, the IFWG technique is:

$$\begin{aligned} &IFWG_{fw}\left(f\theta_1, f\theta_2,\ldots, f\theta_n\right)\\ &=\bigotimes_{j=1}^{n}\left(f\theta_j\right)^{fw_j}\\ &=\left(\prod_{j=1}^{n}\left(fu_j\right)^{fw_j}, 1-\prod_{j=1}^{n}\left(1-fv_j\right)^{fw_j}\right)\end{aligned} \quad (10)$$

where $fw=\left(fw_1, fw_2,..., fw_n\right)^T$ be weight values of $f\theta_j,\ fw_j>0,\sum_{j=1}^{n}fw_j=1.$

3. IFN-ExpTODIM-EDAS technique for managing the MAGDM

Then, IFN-ExpTODIM-EDAS technique is constructed for MAGDM. Let $FA=\left\{FA_1, FA_2,\cdots, FA_m\right\}$ be alternatives, and attributes $FG=\left\{FG_1, FG_2,\cdots, FG_n\right\}$ with weight $fw=\left(fs_1, fs_2,..., fw_n\right)^T$, where $fw_j\in\left[0,1\right]$, $\sum_{j=1}^{n}fw_j=1$ and a set of invited experts $FE=\left\{FE_1, FE_2,\cdots, FE_q\right\}$,let expert's weight values be $f\omega=\left(f\omega_1, f\omega_2,..., f\omega_n\right)^T$, where $f\omega_j\in\left[0,1\right], \sum_{j=1}^{n}f\omega_j=1.$

Then, IFN-ExpTODIM-EDAS technique is constructed for managing the MAGDM (See Figure 1).

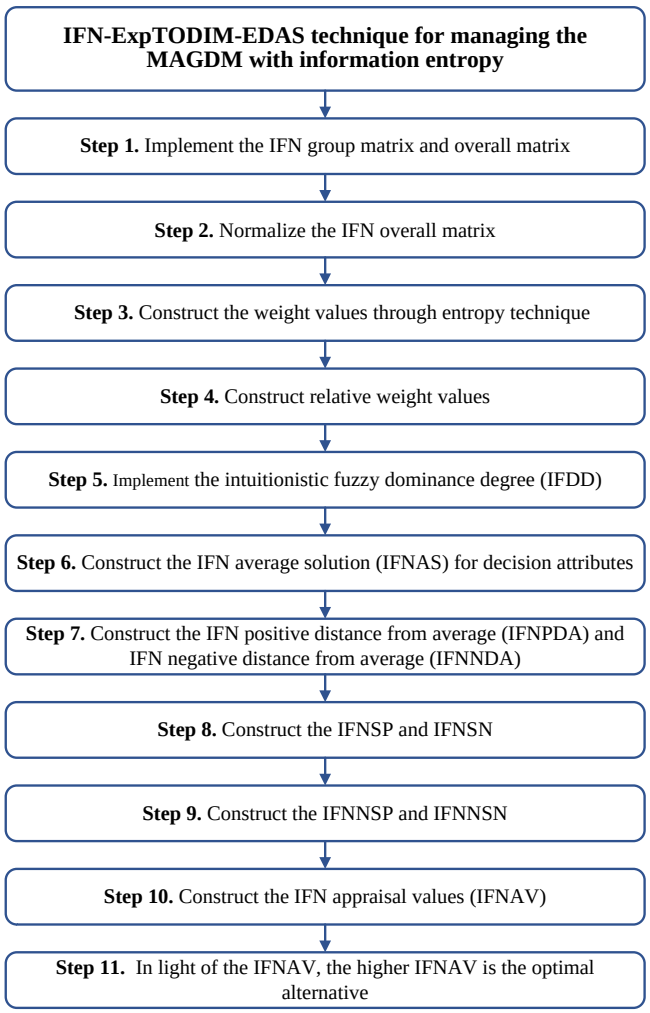

Figure 1. the IFN-ExpTODIM-EDAS technique is constructed for managing the MAGDM with information entropy

3.1. Build and normalize IF-MAGDM information

Step 1. Construct the IFN-matrix $IFN^t = \left[IFN_{ij}^t\right]_{m\times n} = \left(fu_{ij}^{(t)},\ fv_{ij}^{(t)}\right)_{m\times n}$ and construct the average matrix $IFN = \left[IFN_{ij}\right]_{m\times n}$:

$$IFN^t = \left[IFN_{ij}^t\right]_{m\times n} = \begin{array}{c} \\ FA_1 \\ FA_2 \\ \vdots \\ FA_m \end{array} \begin{array}{c} \begin{array}{cccc} FG_1 & FG_2 & \dots & FG_n \end{array} \\ \begin{bmatrix} IFN_{11}^t & IFN_{12}^t & \dots & IFN_{1n}^t \\ IFN_{21}^t & IFN_{22}^t & \dots & IFN_{2n}^t \\ \vdots & \vdots & \vdots & \vdots \\ IFN_{m1}^t & IFN_{m2}^t & \dots & IFN_{mn}^t \end{bmatrix} \end{array} \quad (11)$$

$$IFN = \left[IFN_{ij}\right]_{m\times n} = \begin{array}{c} \\ FA_1 \\ FA_2 \\ \vdots \\ FA_m \end{array} \begin{array}{c} \begin{array}{cccc} FG_1 & FG_2 & \dots & FG_n \end{array} \\ \begin{bmatrix} IFN_{11} & IFN_{12} & \dots & IFN_{1n} \\ IFN_{21} & IFN_{22} & \dots & IFN_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ IFN_{m1} & IFN_{m2} & \dots & IFN_{mn} \end{bmatrix} \end{array} \quad (12)$$

Based on IFWA technique,

the $IFN = \left[IFN_{ij}\right]_{m\times n} = \left(fu_{ij},\ fv_{ij}\right)_{m\times n}$ is:

$$IFN_{ij} = f\omega_1 IFN_{ij}^1 \oplus f\omega_2 IFN_{ij}^2 \oplus \cdots \oplus f\omega_q IFN_{ij}^q = \left(1-\prod_{t=1}^{q}(1-fu_{ij}^{(t)})^{f\omega_t}, \prod_{t=1}^{q}\left(fv_{ij}^{(t)}\right)^{f\omega_t}\right) \quad (13)$$

Step 2. Normalize the $IFN = \left[IFN_{ij}\right]_{m\times n} = \left(fu_{ij},\ fv_{ij}\right)_{m\times n}$ into $NIFN = \left[NIFN_{ij}\right]_{m\times n} = \left(nfu_{ij}, nfv_{ij}\right)_{m\times n}$.

For benefit attributes:

$$NIFN_{ij} = \left(nfu_{ij},\ \ nfv_{ij}\right) = \left(fu_{ij}, fv_{ij}\right) \quad (14)$$

For cost attributes:

$$NIFN_{ij} = \left(nfu_{ij},\ \ nfv_{ij}\right) = \left(fv_{ij}, fu_{ij}\right) \quad (15)$$

3.2. Construct the weight values through entropy technique.

Step 3. Entropy [86] is a useful technique to construct weight. The novel IFN normalized scores $IFNN\text{-}Scores_{ij}$ is constructed based on the scores functions[87]:

$$IFNN\text{-}Scores_{ij} = \frac{nfu_{ij} + nfu_{ij}\left(1-nfu_{ij}-nfv_{ij}\right)}{\sum_{i=1}^{m}\left(nfu_{ij} + nfu_{ij}\left(1-nfu_{ij}-nfv_{ij}\right)\right)}, \quad (16)$$

The IFN Shannon entropy (IFNSE) is constructed:

$$IFNSE_j = -\frac{1}{\ln m}\sum_{i=1}^{m} IFNN\text{-}Scores_{ij} \ln IFNN\text{-}Scores_{ij} \quad (17)$$

and $IFNN\text{-}Scores_{ij} \ln IFNN\text{-}Scores_{ij} = 0$ if $IFNN\text{-}Scores_{ij} = 0$.

Then, the weights $fw = (fw_1, fw_2, \cdots, fw_n)$ is constructed:

$$fw_j = \frac{1 - IFNSE_j}{\sum_{j=1}^{n}\left(1 - IFNSE_j\right)} \tag{18}$$

3.3. IFN-ExpTODIM-EDAS technique for managing the MAGDM

Then, the IFN-ExpTODIM-EDAS technique is constructed for managing the MAGDM.

Step 4. Construct relative weight values of FG_j as:

$$rfw_j = fw_j \Big/ \max_j fw_j, \tag{19}$$

Step 5. The intuitionistic fuzzy dominance degree (IFDD) $IFDD_j(FA_i, FA_t)$ of FA_i over FA_t for FG_j is constructed through Eqs.(20)

$$IFDD_j(FA_i, FA_t) == \begin{cases} \dfrac{rfw_j \times \left(1 - 10^{-\rho IFNDM\left(NIFN_{ij}, NIFN_{tj}\right)}\right)}{\sum_{j=1}^{n} rfw_j} & if\ SF\left(NIFN_{ij}\right) > SF\left(NIFN_{tj}\right) \\ 0 & if\ SF\left(NIFN_{ij}\right) = SF\left(NIFN_{tj}\right) \\ -\dfrac{1}{\pi}\dfrac{\sum_{j=1}^{n} rfw_j \times \left(1 - 10^{-\rho IFNDM\left(NIFN_{ij}, NIFN_{tj}\right)}\right)}{rfw_j} & if\ SF\left(NIFN_{ij}\right) < SF\left(NIFN_{tj}\right) \end{cases} \tag{20}$$

where π is from the Tversky and Kahneman [88] and $\pi \in [1, 5]$ and ρ indicates that the curvature function [89].

The dominance degree $IFDD_j(FA_i)(j = 1, 2, \cdots, n)$ for FG_j is constructed:

$$IFDD_j(FA_i) = \left[IFDD_j(FA_i, FA_t)\right]_{m \times m}$$

$$= \begin{array}{c} \\ FA_1 \\ FA_2 \\ \vdots \\ FA_m \end{array} \begin{array}{c} \begin{array}{cccc} FA_1 & FA_2 & \cdots & FA_m \end{array} \\ \begin{bmatrix} 0 & IFDD_j(FA_1, FA_2) & \cdots & IFDD_j(FA_1, FA_m) \\ IFDD_j(FA_2, FA_1) & 0 & \cdots & IFDD_j(FA_2, FA_m) \\ \vdots & \vdots & \cdots & \vdots \\ IFDD_j(FA_m, FA_1) & IFDD_j(FA_m, FA_2) & \cdots & 0 \end{bmatrix} \end{array}$$

The overall dominance degree of FA_i over other alternatives for FG_j is constructed:

$$IFDD_j(FA_i) = \sum_{t=1}^{m} IFDD_j(FA_i, FA_t) \tag{21}$$

The overall dominance matrix is constructed:

$$IFDD=\left(IFDD_{ij}\right)_{m\times n}$$
$$=\begin{bmatrix} & FG_1 & FG_2 & \cdots & FG_n \\ FA_1 & \sum_{t=1}^{m} IFDD_1\left(FA_1,FA_t\right) & \sum_{t=1}^{m} IFDD_2\left(FA_1,FA_t\right) & \cdots & \sum_{t=1}^{m} IFDD_n\left(FA_1,FA_t\right) \\ FA_2 & \sum_{t=1}^{m} IFDD_1\left(FA_2,FA_t\right) & \sum_{t=1}^{m} IFDD_2\left(FA_2,FA_t\right) & \cdots & \sum_{t=1}^{m} IFDD_n\left(FA_2,FA_t\right) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ FA_m & \sum_{t=1}^{m} IFDD_1\left(FA_m,FA_t\right) & \sum_{t=1}^{m} IFDD_2\left(FA_m,FA_t\right) & \cdots & \sum_{t=1}^{m} IFDD_n\left(FA_m,FA_t\right) \end{bmatrix}$$

Step 6. Construct the IFN average solution (IFNAS) for decision attributes.

$$IFNAS=\left[IFNAS_j\right]_{1\times n}=\left[\frac{\sum_{i=1}^{m} IFDDV_{ij}}{m}\right]_{1\times n} \tag{22}$$

$$IFDDV_{ij}=\frac{IFDD_{ij}-IFNIS_j}{IFPIS_j-IFNIS_j}, \tag{23}$$

$$IFPIS_j=\max_{j=1}^{n} IFDD_{ij}, IFNIS_j=\min_{j=1}^{n} IFDD_{ij} \tag{24}$$

Step 7. Construct the IFN positive distance from average (IFNPDA) and IFN negative distance from average (IFNNDA):

$$IFNPDA_{ij}=\left[IFNPDA_{ij}\right]_{m\times n}$$
$$=\frac{\max\left(0,\left(IFDDV_{ij}-IFNAS_j\right)\right)}{IFNAS_j}, \tag{25}$$

$$IFNNDA_{ij}=\left[IFNNDA_{ij}\right]_{m\times n}$$
$$=\frac{\max\left(0,\left(IFNAS_j-IFDDV_{ij}\right)\right)}{IFNAS_j}, \tag{26}$$

Step 8. Construct the $IFNSP_i$ and $IFNSN_i$.

$$\begin{aligned} IFNSP_i&=\sum_{j=1}^{n} fw_j\cdot IFNPDA_{ij}, \\ IFNSN_i&=\sum_{j=1}^{n} fw_j\cdot IFNNDA_{ij} \end{aligned}, \tag{27}$$

Step 9. Normalized the $IFNSP_i$ and $IFNSN_i$ to get the $IFNNSP_i$ and $IFNNSN_i$:

$$\begin{aligned} IFNNSP_i&=\frac{IFNSP_i}{\max_i\left(IFNSP_i\right)}, \\ IFNNSN_i&=1-\frac{IFNSN_i}{\max_i\left(IFNSN_i\right)} \end{aligned}, \tag{28}$$

Step 10. Construct the IFN appraisal values (IFNAV):

$$IFNAV_i=\frac{1}{2}\left(IFNNSP+IFNNSN_i\right) \tag{29}$$

Step 11. In light of the IFNAV, the higher IFNAV, the optimal alternative is.

4. An empirical example and comparative analysis

4.1. An empirical example for supervision effectiveness evaluation of SMS financial institutions in rural areas

At present, the information asymmetry between rural small and medium-sized financial institutions and financial regulatory agencies in China is very serious, far stronger than other types of financial institutions. This is caemployed by the following reasons. One is dispersed distribution, separated from financial regulatory agencies in different locations. The vast majority of rural small and medium-sized financial institutions are first level legal entities located in counties, with a wide distribution area, even in remote mountainous areas. However, the grassroots units of financial regulatory agencies are located in central cities of cities and states, often far apart, making it difficult to transmit information. The second is that obtaining information is difficult and the quality of

information is not high. On the one hand, the management foundation of rural small and medium-sized financial institutions is weak, the financial information database is not sound, and there is a lack of modern information collection, processing, and reporting techniques, making it difficult for financial regulatory agencies to obtain complete relevant data and information from them; On the other hand, the loan recipients of rural small and medium-sized financial institutions are mostly farmers and small and medium-sized enterprises, often unable to provide the necessary information. They mainly rely on soft information for loan decision-making, which is difficult to transmit. Thirdly, the professional quality of employees is relatively poor and the operational risks are high. Due to historical reasons, the average education level of employees in rural small and medium-sized financial institutions is relatively low, with complex sources and a lack of systematic business training. Therefore, in its credit business, there are more adverse selection, moral hazard, and operational risk, and the relevant personnel who cause these phenomena often deliberately evade the supervision of financial regulatory agencies. The supervision effectiveness evaluation of SMS financial institutions in rural areas is a MAGDM. Therefore, the supervision effectiveness evaluation of SMS financial institutions in rural areas is constructed to verify the IFN-ExpTODIM-EDAS technique. There are five SMS financial institutions in rural areas $FA_i\left(i=1,2,3,4,5\right)$ to select. The experts choose four attributes to evaluate the five SMS financial institutions in rural areas[90]: ① FG_1 is guided supervision for rural small and medium-sized financial institutions. ②FG_2 is cost of supervision of rural small and medium-sized financial institutions. ③FG_3 is risk supervision for rural small and medium-sized financial institutions. ④FG_4 is mechanism supervision for rural small and medium-sized financial institutions. The five possible SMS financial institutions in rural areas $FA_i\left(i=1,2,3,4,5\right)$ are to be managed with linguistic scale with four attributes through three information experts $FE_t\left(t=1,2,3\right)$ (Suppose expert's weight is $\left(0.25,0.40,0.35\right)$.

Table 1. Linguistic scale and IFNs

Linguistic information Terms	IFNs
Exceedingly Terrible-FET	(0.10,0.80)
Very Terrible-FVT	(0.20,0.70)
Terrible-FT	(0.30,0.60)
Medium-FM	(0.50,0.50)
Well-FW	(0.65,0.30)
Very Well-FVW	(0.75,0.20)
Exceedingly Well-FEW	(1.0,0.0)

The IFN-ExpTODIM-EDAS technique is constructed to manage the supervision effectiveness

evaluation of SMS financial institutions in rural areas. (See Table 2-4).

Step 1. Manage the IFN-matrix $IFN^t = \left[IFN_{ij}^t \right]_{5\times4}$

Table 2. Evaluation information by FE_1

	FG_1	FG_2	FG_3	FG_4
FA_1	FVW	FW	FM	FT
FA_2	FVT	FT	FW	FVW
FA_3	FT	FM	FM	FW
FA_4	FT	FM	FW	FVW
FA_5	FM	FW	FVT	FVT

Table 3. Evaluation information by FE_2

	FG_1	FG_2	FG_3	FG_4
FA_1	FM	FT	FVW	FW
FA_2	FVT	FM	FVW	FT
FA_3	FT	FW	FM	FVW
FA_4	FVW	FW	FVT	FM
FA_5	FM	FW	FVT	FVW

Table 4. Evaluation information by FE_3

	FG_1	FG_2	FG_3	FG_4
FA_1	FVW	FW	FM	FVT
FA_2	FW	FM	FT	FVW
FA_3	FM	FW	FVW	FVT
FA_4	FVT	FVT	FVW	FM
FA_5	FT	FVW	FVT	FM

Then through the IFWG, the $IFN = \left[IFN_{ij} \right]_{5\times4}$ is constructed (See Table 5).

Table 5. The $IFN = \left[IFN_{ij} \right]_{5\times4}$

	FG_1	FG_2	FG_3	FG_4

FA_1	(0.31,0.64)	(0.42,0.63)	(0.27,0.73)	(0.42,0.49)
FA_2	(0.47,0.52)	(0.36,0.54)	(0.68,0.29)	(0.62,0.35)
FA_3	(0.45,0.46)	(0.37,0.63)	(0.49,0.41)	(0.26,0.64)
FA_4	(0.43,0.57)	(0.21,0.76)	(0.57,0.43)	(0.48,0.52)
FA_5	(0.26,0.74)	(0.45,0.49)	(0.65,0.35)	(0.62,0.37)

$NIFN = \left[NIFN_{ij} \right]_{5\times4}$ (See Table 6).

Step 2. Normalize the $IFN = \left[IFN_{ij} \right]_{5\times4}$ into

Table 6. The $NIFN = \left[NIFN_{ij} \right]_{5\times4}$

	FG_1	FG_2	FG_3	FG_4
FA_1	(0.31,0.64)	(0.42,0.63)	(0.27,0.73)	(0.42,0.49)
FA_2	(0.47,0.52)	(0.36,0.54)	(0.68,0.29)	(0.62,0.35)
FA_3	(0.45,0.46)	(0.37,0.63)	(0.49,0.41)	(0.26,0.64)
FA_4	(0.43,0.57)	(0.21,0.76)	(0.57,0.43)	(0.48,0.52)
FA_5	(0.26,0.74)	(0.45,0.49)	(0.65,0.35)	(0.62,0.37)

$rfw = \{0.3478, 0.9516, 1.0000, 0.6884\}$

Step 3. Compute the weight values:

$$fw_1 = 0.1164,\ fw_2 = 0.3185$$
$$fw_3 = 0.3347,\ fw_4 = 0.2304.$$

Step 5. Construct the $IFDD = \left(IFDD_{ij} \right)_{5\times4}$ (See table 7):

Step 4. Construct the relative weight values:

Table 7. The $IFDD = \left(IFDD_{ij} \right)_{5\times4}$

	FG_1	FG_2	FG_3	FG_4
FA_1	0.6780	-1.2002	-1.0842	-0.8865
FA_2	-0.4076	0.9477	0.7316	-0.4989
FA_3	-0.4854	-0.0609	-0.9841	-1.4063
FA_4	0.2701	-0.5587	-0.2438	1.0554
FA_5	-1.5241	0.4236	0.2295	0.3516

Step 6. Construct the IFNAS (See table 8).

Table 8. The IFNAS

	FG_1	FG_2	FG_3	FG_4
IFNAS	0.5587	0.5170	0.4483	0.4588

Step 7. Construct the IFNPDA and IFNNDA (See table

9-10):

Table 9. The IFNPDA

	FG_1	FG_2	FG_3	FG_4
FA_1	0.4413	0.0000	0.0000	0.0000
FA_2	0.0000	0.4830	0.5517	0.0000
FA_3	0.0000	0.0134	0.0000	0.0000
FA_4	0.2561	0.0000	0.0145	0.5412
FA_5	0.0000	0.2390	0.2752	0.2553

Table 10. The IFNNDA

	FG_1	FG_2	FG_3	FG_4
FA_1	0.0000	0.5170	0.4483	0.2476
FA_2	0.0517	0.0000	0.0000	0.0901
FA_3	0.0870	0.0000	0.3931	0.4588
FA_4	0.0000	0.2183	0.0000	0.0000
FA_5	0.5587	0.0000	0.0000	0.0000

Step 8. Construct the IFNSP and IFNSN (See Table 11).

Table 11. The IFNSP and IFNSN

	IFNSP	IFNSN
FA_1	0.0514	0.3718
FA_2	0.3385	0.0268
FA_3	0.0043	0.2474
FA_4	0.1594	0.0695
FA_5	0.2271	0.0650

12.

Step 9. Construct the IFNNSP and IFNNSN is in Table

Table 12. The IFNNSP and IFNNSN

	IFNNSP	IFNNSN
FA_1	0.1518	0.0000
FA_2	1.0000	0.9279
FA_3	0.0126	0.3345
FA_4	0.4708	0.8129
FA_5	0.6708	0.8251

Step 10. Construct the IFNAV (See Table 13).

Table 13. The IFNAV

	IFNAV	Order
FA_1	0.5399	3
FA_2	0.6672	1
FA_3	0.4128	4
FA_4	0.6479	2
FA_5	0.3354	5

Step 11. In light of the IFNAV information, the order is: $FA_2 > FA_4 > FA_1 > FA_3 > FA_5$ and FA_2 is the best SMS financial institution in rural areas.

4.2. Comparative analysis

Then, the IFN-ExpTODIM-EDAS technique is fully compared with IFWA technique[91] and IFWG technique[82], intuitionistic fuzzy normalized WBM (IFNWBM) technique[92], dual generalized intuitionistic fuzzy WBM (DGIFWBM) technique[93], intuitionistic fuzzy dice similarity measure(IF-DSM) [94], IF-PROMETHEE technique [95], IF-MARCOS technique [96], intuitionistic fuzzy FUCOM-WASPAS (IF-FUCOM-WASPAS) technique[97] and IF-TODIM technique [98]. The comparative information results are constructed in Table 12 and Figure 2.

Table 12. Order for different techniques

	Order
IFWA technique[91]	$FA_2 > FA_4 > FA_1 > FA_3 > FA_5$
IFWG technique[82]	$FA_2 > FA_4 > FA_3 > FA_1 > FA_5$
IFNWBM technique[92]	$FA_2 > FA_4 > FA_3 > FA_1 > FA_5$

DGIFWBM technique[93]	$FA_2 > FA_4 > FA_3 > FA_1 > FA_5$
IF-DSM technique [94]	$FA_2 > FA_4 > FA_1 > FA_3 > FA_5$
IF- PROMETHEE technique [95]	$FA_2 > FA_4 > FA_1 > FA_3 > FA_5$
IF-MARCOS technique [96]	$FA_2 > FA_4 > FA_1 > FA_3 > FA_5$
IF-FUCOM-WASPAS technique[97]	$FA_2 > FA_4 > FA_1 > FA_3 > FA_5$
IF-TODIM technique [98]	$FA_2 > FA_4 > FA_3 > FA_1 > FA_5$

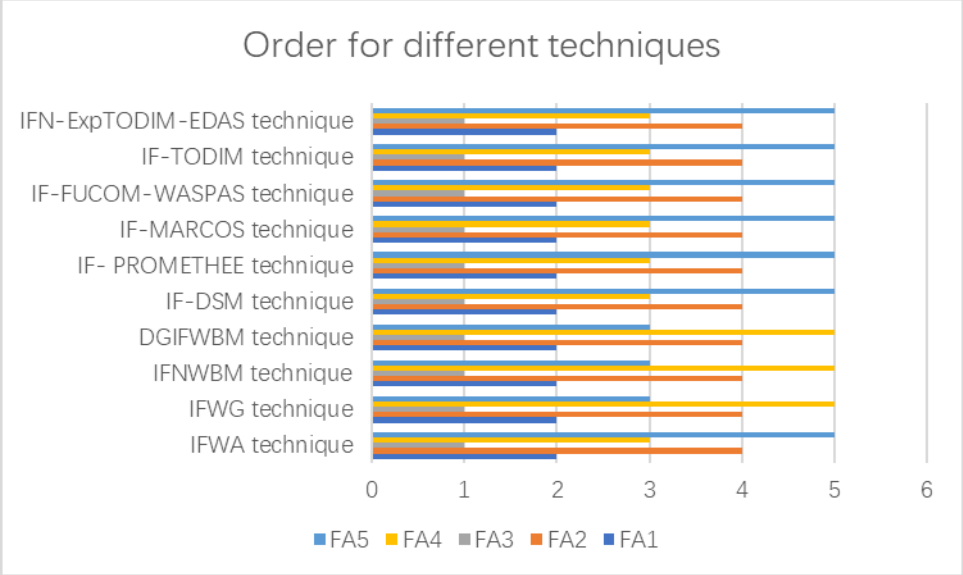

Figure 2. Order for different techniques

Furthermore, the order similarity degree between the IFWA technique[91] and IFWG technique[82], intuitionistic fuzzy normalized WBM (IFNWBM) technique[92], dual generalized intuitionistic fuzzy WBM (DGIFWBM) technique[93], intuitionistic fuzzy dice similarity measure(IF-DSM) technique [94], IF-PROMETHEE technique [95], IF-MARCOS technique [96], intuitionistic fuzzy FUCOM-WASPAS (IF-FUCOM-WASPAS) technique[97], IF-TODIM technique [98] and the proposed IFN-ExpTODIM-EDAS technique in this paper was analyzed with WS coefficients [99], the calculating results are constructed in Table 13.

Table 13. WS coefficient calculation

	IFN-ExpTODIM-EDAS technique	IFWA technique	IFWG technique	IFNWBM technique
FA_1	2	2	2	2
FA_2	4	4	4	4

FA_3	1	1	1	1
FA_4	3	3	5	5
FA_5	5	5	3	3
Coefficients	WS	1.0000	0.8594	0.8594

	IFN-ExpTODIM-EDAS technique	DGIFWBM technique	IF-DSM technique	IF-PROMETHEE technique
FA_1	2	2	2	2
FA_2	4	4	4	4
FA_3	1	1	1	1
FA_4	3	5	3	3
FA_5	5	3	5	5
Coefficients	WS	0.8594	1.0000	1.0000

	IFN-ExpTODIM-EDAS technique	IF-MARCOS technique	IF-FUCOM-WASPAS technique	IF-TODIM technique
FA_1	2	2	2	2
FA_2	4	4	4	4
FA_3	1	1	1	1
FA_4	3	3	3	3
FA_5	5	5	5	5
Coefficients	WS	1.0000	1.0000	1.0000

The WS coefficient calculation shows that the order result of IFWA technique[91], intuitionistic fuzzy dice similarity measure(IF-DSM) technique [94], IF-PROMETHEE technique [95], IF-MARCOS technique [96], intuitionistic fuzzy FUCOM-WASPAS (IF-FUCOM-WASPAS) technique[97], IF-TODIM technique [98] is same with the order result of the proposed IFN-ExpTODIM-EDAS technique; the WS coefficient shows the ranking results of the proposed IFN-ExpTODIM-EDAS technique is slightly different to the ranking results of IFWG technique[82], intuitionistic fuzzy normalized WBM (IFNWBM) technique[92] and dual generalized intuitionistic fuzzy WBM (DGIFWBM) technique[93]. Furthermore, the reason for this subtle difference is that IFWG technique[82] emphasize the individual's influence on decision result, while intuitionistic fuzzy normalized WBM (IFNWBM) technique[92] and dual generalized intuitionistic fuzzy WBM (DGIFWBM) technique[93] emphasize the interrelationship influence among the input information.

Therefore, our proposed IFN-ExpTODIM-EDAS technique is effective and reliable MAGDM technique for supervision effectiveness evaluation of SMS financial institutions in rural areas. Thus, the main advantages of the proposed IFN-ExpTODIM-EDAS technique are outlined: (1) the proposed IFN-ExpTODIM-EDAS technique not only handles the uncertainty in real MAGDM issues for supervision effectiveness evaluation of SMS financial institutions in rural areas, but also portrays the DMs' psychological behavior during the supervision effectiveness evaluation of SMS financial institutions in rural areas. (2) the proposed IFN-ExpTODIM-EDAS technique analyze the behavior of the TODIM and EDAS technique as MADM techniques when they are hybridized. The main disadvantages of the IFN-ExpTODIM-EDAS technique fails to pay attention to the consensus issues and regret theory in the practical MAGDM for supervision effectiveness evaluation of SMS financial institutions in rural areas.

5. Conclusion

The effectiveness of supervision cannot be separated from innovative work in supervision, which is also one of the ways to achieve the regulatory goals of rural small and medium-sized financial institutions. It can promote the transformation of the management mechanism of rural small and medium-sized financial institutions, strengthen their environmental regulatory governance, and attach importance to the development plan of rural finance in China. The effectiveness of supervision of rural small and medium-sized financial institutions is a challenging research topic, which can organically combine regulatory effectiveness with rural small and medium-sized financial institutions, actively address and solve their shortcomings, make new breakthroughs in the construction of competition mechanisms in the financial market, and take the supervision of rural small and medium-sized financial institutions to a new level. The supervision effectiveness evaluation of SMS financial institutions in rural areas is MAGDM. Recently, the ExpTODIM and EDAS technique has been employed to manage MAGDM. The IFSs are employed as a technique for portraying uncertain information during the supervision effectiveness evaluation of SMS financial institutions in rural areas. In this work, the IFN-ExpTODIM-EDAS technique is cultivated to manage the MAGDM under IFSs. Finally, a numerical case study for supervision effectiveness evaluation of SMS financial institutions in rural areas is constructed to verify the IFN-ExpTODIM-EDAS technique. The main contributions of this work are managed: (1) the ExpTODIM and EDAS technique was extended to IFSs; (2) Information Entropy is employed to manage weight values under IFSs. (3) the IFN-ExpTODIM-EDAS technique is founded to manage the MAGDM under IFSs; (4) a numerical example for supervision effectiveness evaluation of SMS financial institutions in rural areas; (5) some comparative analysis is employed to verify the IFN-ExpTODIM-EDAS technique.

Based on the comprehensive analysis of this component, the following are some strategies and management suggestions to improve the effectiveness of rural financial supervision, in order to facilitate further research in the future: (1) On the one hand, it is necessary to implement classified supervision and upgrading of rural small and medium-sized financial institutions. For institutions of different regions and types, the principle of adapting to local conditions, treating them differently, advancing in stages, and gradually reaching standards should be followed. On the other hand, there is a unified regulatory standard and assessment indicator system. At present, there is a vague phenomenon in the regulation of

rural small and medium-sized financial institutions in terms of main indicators such as capital adequacy ratio, classification standards for non-performing loans, and proportion of large loans. Inconsistent language descriptions of regulatory standards and requirements can lead to unclear risk bases for financial institutions, affecting and reducing the effectiveness of regulation. (2) In order to improve and assess the effectiveness of the supervision of rural small and medium-sized financial institutions, it is necessary to build a complete regulatory indicator system for rural small and medium-sized financial institutions based on the characteristics, development status, and social responsibility of rural small and medium-sized financial institutions in China, and around the regulatory goals, according to the ways and techniques that can achieve this goal. Through this regulatory indicator system, the behavior of rural small and medium-sized financial institutions is incentivized and constrained, while also improving the work efficiency of regulatory agencies and reducing their own work costs.

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