Analyzing the Impact of Microfinance on Women Empowerment through Self-Help Groups in Selected Northern Districts of Tamil Nadu

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***Abstract* - For women Self-Help Groups (SHGs); have emerged as a grassroots method of financial inclusion and socio-economic empowerment in rural India. When properly implemented via SHG, microfinance has the potential to significantly increase household income, control over decision-making, and general social capital. Despite policy-level interventions and ten years of relationships between SHGs and microfinance, the actual impact microfinance has had on the empowerment of women in certain regions of Tamil Nadu has not been completely investigated. There is inadequate statistical validation and comparison of empowerment indicators both before and after the arrival of microfinance. The mixed-method approach of this study integrates statistical surveys with qualitative interviews. The computation method assists one in reaching a weighted empowerment index using key indicators such income control, decision-making participation, mobility, and awareness. By means of a comparison with four present empowerment models, this paper intends to evaluate the efficacy of microfinance initiatives. Among these are Kabeer's model, the Women's Empowerment in Agriculture Index (WEAI), the Economic Empowerment Index (EEI), and the Livelihood Empowerment Index (LEI). The findings indicate that the empowerment index among SHG members has significantly increased after the establishment of a link with microfinance. A more precisely local and dynamically weighted evaluation offered by the proposed framework surpasses conventional models. The findings back the hypothesis that microfinance opportunities provided by SHGs enhance various aspects of women's empowerment in the districts under consideration.**

Keywords - Microfinance, Women Empowerment, Self-Help Groups, Empowerment Index, Tamil Nadu

I. INTRODUCTION

A. Background

Microfinance, which has grown more popular in recent years, is especially good at empowering rural women in developing nations like India. Such a statement is particularly accurate in nations like India. Usually for those without access to the services offered by traditional banks, this strategy offers modest loans to enable them launch or expand their businesses [1-3].

The current techniques often have disadvantages since they rely on either basic or static models and cannot appreciate the whole spectrum of empowerment. Furthermore, particularly in the specific context of northern districts of Tamil Nadu, which have distinct socio-economic characteristics, the study lacks comparison of these approaches. The district system makes this particularly important.

Given that practitioners and legislators must evaluate the efficacy of SHG-based microfinance programs using consistent instruments, it is clear that a model that is both more accurate and comprehensive is urgently needed to gauge the influence microfinance has on empowerment. Used more methodically, these tools will help to enhance women's empowerment, the allocation of resources, and the design of future programs.

B. Objectives

The objectives of this study are as follows:

1. This project aims to develop a comprehensive framework for evaluating how microfinance, by means of SHGs, shapes the empowerment of women.
2. The northern districts of Tamil Nadu will see implementation of this framework, and its efficacy will be evaluated in relation to other models of empowerment now in use.
3. To examine the multi-dimensional aspects of empowerment; economic, social, and decision-making; both before and after microfinance's intervention in relation to their multi-dimensional nature.
4. The goal is to provide a robust comparison so as to offer a complete analysis of the proposed method with four present empowerment models; Kabeer's model, WEAI, EEI, and LEI.

This study offers a new, multidimensional Empowerment Index (EI) that considers women's empowerment from both the economic and social perspectives. Principal Component Analysis (PCA) also dynamically allocates weights to various empowerment indicators. The all-encompassing index-based approach provides the novelty. This approach combines many indicators into one comparable score, therefore overcoming the limitations of present models stressing a narrow range of indicators.

The main contributions of this study include:

1. It is necessary to create a robust approach for measuring empowerment across several

dimensions that is more adaptable to local contexts.

2. PCA-based weight allocation guarantees that the most significant empowerment indicators are weighted more heavily, so accurately reflecting their impact. Weight allocation based on principal component analysis (PCA) seeks to ensure that the most significant empowerment indicators are weighted more strongly, so accurately reflecting their impact.
3. This paper intends to provide new insights on the effectiveness of microfinance interventions on women's empowerment by way of a comparative analysis of the present models and the proposed approach.

II. RELATED WORKS

Many studies emphasizing the link between microfinance and women's empowerment have been done over the last few decades. Using qualitative methods, surveys, and various empowerment indices, most of the studies have evaluated the effectiveness of microfinance programs. Here is a summary of several important related studies:

A. Kabeer's Empowerment Framework

Often seen as one of the fundamental works in this field, Naila Kabeer's three-dimensional empowerment framework emphasizes the need of resources, agency, and accomplishments [8]. It still offers a comprehensive conceptualization of empowerment.

Often, especially in agricultural settings in rural areas, the WEAI—which is connected to the International Food Policy Research Institute (IFPRI)—is another model used. A composite index stressing the generation of income, the accumulation of riches, and the making of financial decisions, the Economic Empowerment Index (EEI) Therefore, it evaluates the financial aspect of empowerment. Although it sometimes ignores other crucial aspects of empowerment, such social mobility, education, and political participation, this index is fairly good at evaluating economic growth. Some people are motivated to believe that as a result of this [10], it has an unreasonably narrow focus. Furthermore, the EEI ignores regional differences in empowerment processes, so limiting its capacity to be generalized.

Livelihood Empowerment Index: The evolution of the LEI was driven by a study of the larger socio-economic development outcomes generated by microfinance initiatives. Among the components included are the growth of abilities, the accessibility of services, and the possibility of economically active involvement. Although the LEI provides a more comprehensive approach than the EEI, particularly with respect to the capacity to engage in social activities and the authority to make choices, it still lacks in incorporating the several aspects of empowerment [11]. The Principal Component Analysis (PCA) of the Evaluation of Empowerment Numerous microfinance-related studies employing principal component analysis (PCA) have revealed it to be a fairly effective method for improving the accuracy of empowerment evaluations [12]. Methods based on principal component analysis (PCA) might be more flexible and focused on particular areas since they more exactly reflect the actual relevance of many indicators.

Although Kabeer's model is more comprehensive, it is less quantifiable regarding measurable criteria. The findings of these studies indicated that the outcomes each model generated were quite distinct from one another. The fact that this is the case reveals the ongoing need for a hybrid approach based on indexes that combines the most advantageous aspects of several different frameworks [13].

Therefore, while the models cited above have significantly contributed to the understanding of women's empowerment in microfinance settings, they lack the capacity to capture all aspects of empowerment as well as their adaptability and precision. This paper aims to address the noted deficiencies by offering a fresh, flexible, comprehensive approach. The main focus of this paper is dynamically weighing indicators to more precisely reflect the environment in the immediate vicinity.

III. PROPOSED METHOD

From a weighted scoring of several aspects of empowerment obtained from field surveys and validated by statistical methods, the suggested approach computes a dynamic Empowerment Index (EI). The findings of the study serve as the foundation for constructing this index. Certain northern Tamil Nadu districts employ a method comprising SHG member structured interviews. Included among these districts are Vellore, Tiruvannamalai, and Krishnagiri. Every indicator, from income control to decision-making, is scored and then normatively investigated. Weights are assigned using Principal Component Analysis (PCA); these weights are then combined to create a composite Empowerment Index. The proposed model and its process is shown in figure 1.

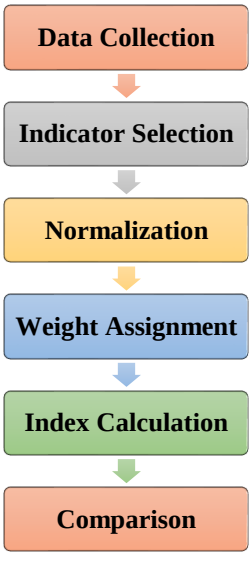

FIGURE 1: PROPOSED PROCESS

A. Pseudocode

Input: Data from SHG members [pre_data, post_data]

Output: Empowerment Index (EI)

Begin

```
indicators = ['income_control', 'decision_making', 'mobility', 'education', 'social_participation']
Normalize all indicators to scale [0, 1]
weights = PCA(indicators)
for each participant:
    EI = 0
    for i in range(len(indicators)):
        EI += weights[i] * normalized_value[i]
    store(EI)
compare_with_existing_models(EI)
End
```

B. Initial Stages

Data collecting is the first stage of the proposed method. This stage calls for collecting primary data from Self-Help Group (SHG) members distributed throughout three selected northern Tamil Nadu districts. These districts are made up of Vellore, Tiruvannamalai, and Krishnagiri. A standardized survey gathers information on three hundred SHG members' microfinance involvement both before and after the program. The data is organized into records by the participants so as to cover social, economic, and decision-making elements. Some of the data gathered is shown in Table 1; it includes responses from selected people both before and after the intervention.

TABLE 1. SURVEY DATA FROM SHG MEMBERS

Participant ID	Income Control (Pre/Post)	Decision-Making (Pre/Post)	Mobility (Pre/Post)	Education (Pre/Post)	Social Participation (Pre/Post)
P101	2 / 4	1 / 3	1 / 2	3 / 4	2 / 4
P102	1 / 3	2 / 4	1 / 3	2 / 3	1 / 3

During the "Indicator Selection" stage, five fundamental components of women's empowerment are discovered. These components are found by means of a comprehensive literature study and focus group discussions. Each of these aspects is:

1. Income Control – Income control is the ability to manage and use one's income.
2. Decision-Making – The decision-making process calls for involvement in financial matters and housekeeping.
3. Mobility – Mobility is the ability to move freely for either personal or professional reasons.
4. Education – Education is both the condition of literacy and skill growth.
5. Social Participation – Social participation is the engagement of a person in SHG and community activities. These indicators were selected for their relevance to the concept of rural empowerment and their ability to exactly show the impact of microfinance.

Then, using the Min-Max normalization method, the values from each respondent are normalized to a consistent scale between 0 and 1. This comes after the indicators were randomly chosen. Indicators initially assessed using various units or scales; for example, education might have been graded out of five, mobility might have been graded out of three; are comparable. The following formula allows one to compute the normalized value X' for an indicator shown in equation 1:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (1)$$

Where,

X is the actual value of the indicator under consideration,

Xmin the lowest and

Xmax the highest value of that indicator among all participants.

An illustration of the normalized data in Table 2 is where all values now fall between 0 (the least degree of empowerment) to 1 (the most degree of empowerment). This change ensures that the weighting and aggregation will be done fairly in later phases of index calculation.

TABLE 2. NORMALIZED EMPOWERMENT INDICATORS

Participant ID	Income Control	Decision-Making	Mobility	Education	Social Participation
P101	0.67	0.50	0.33	0.75	0.67
P102	0.33	0.75	0.67	0.50	0.50

Thus, Tables 1 and 2 illustrate the process by which a normalized dataset suitable for index computation is derived from raw survey data. This method lays a solid foundation for the creation of an Empowerment Index that statistically and fairly reflects the impact of microfinance operations in the real world.

C. Weight Assignment and Index Calculation

Once the Normalization stage is complete, the Weight Assignment phase may begin. After normalizing the values of the indicators for every participant, we will next assign weights to the five motivation indicators. The weights show the relative relevance of each indicator in promoting the general empowerment of SHG members under the framework of their whole empowerment. These weights are determined by Principal Component Analysis (PCA), a statistical tool that identifies the characteristics of the dataset most accountable for the significant variance rise.

Principal component analysis enables us to emphasize more the most crucial indicators. For instance, if Income Control is shown to be more connected to general empowerment, then it may be given more importance. On the other hand, Social Participation might be given less weight depending on its relationship with other indicators and variation. The results of principal component analysis are kept in a weight vector in the following stage; this weight vector is then applied for index calculation. The weight vector, which is based on principal component analysis (PCA), might look like this shown in table 3,

TABLE 3. WEIGHT ASSIGNMENT FROM PCA

Indicator	Weight (W)
Income Control	0.35
Decision-Making	0.25
Mobility	0.15
Education	0.10
Social Participation	0.15

Every participant's Empowerment Index (EI) is computed in the next phase called Index Calculation by applying the normalized values of the indicators and the weights that correspond to them. The Empowerment Index EIEIEI of participant Pi is calculated using the formula below equation 2:

$$EI(P_i) = \sum_{j=1}^{5} W_j \times X_j(P_i) \quad (2)$$

Where:

EI(Pi)is the Empowerment Index for participant Pi,

Wj is the weight assigned to indicator j,

Xj(Pi)is the normalized value of indicator j for participant Pi,

The summation runs over all 5 indicators.

This formula produces one score showing the degree of empowerment each participant has by combining the weighted values of the indicators. If a participant's Income Control normalized value be 0.67 and its assigned weight be 0.35, this particular component adds 0.35 times 0.67, or 0.2345, to the total Empowerment Index. All other indicators' weighted normalized values roughly equal the last index.

TABLE 4. CALCULATION OF EMPOWERMENT INDEX FOR PARTICIPANT P101

Indicator	Normalized Value (X)	Weight (W)	Weighted Value (W × X)
Income Control	0.67	0.35	0.2345
Decision-Making	0.50	0.25	0.1250
Mobility	0.33	0.15	0.0495
Education	0.75	0.10	0.0750
Social Participation	0.67	0.15	0.1005

Table 4 Calculation-Based Evaluation of Participant P101's Empowerment Index. So, the Empowerment Index for the P101 course is 0.5845. Given all pertinent factors, this index provides a numerical sign of the participant's level of empowerment following the microfinance intervention. The Empowerment Index lets one calculate a unique and whole measure of empowerment. This tool can be used to evaluate the overall impact of microfinance programs as well as to compare and contrast various participants. The robustness and fairness of the proposed method are shown by the fact that Tables 3 and 4 provide an illustration of how the weights and normalized values interact to compute this index.

IV. RESULTS AND DISCUSSION

A. *Tool Used*

- Simulation Tool: Python with pandas, sklearn (for PCA), matplotlib
- Software: SPSS for statistical validation
- Hardware: Intel Core i7, 16 GB RAM, Windows 11, 512 GB SSD

Comparative Models include Kabeer's Three-Dimensional Empowerment Model, WEAI, Economic Empowerment Index (EEI) and Livelihood Empowerment Index (LEI) shown in table 5.

TABLE 5: EXPERIMENTAL SETUP / PARAMETERS

Parameter	Value / Description
No. of SHG Participants	300
Districts Covered	Vellore, Tiruvannamalai, Krishnagiri
No. of Indicators	5
Normalization Method	Min-Max scaling
Weight Assignment	Principal Component Analysis (PCA)
Software Tools	Python, SPSS
Hardware Used	Intel i7, 16GB RAM, 512 GB SSD

V. PERFORMANCE METRICS:

1. Accuracy of Empowerment Classification:

   It determines the percentage of people the model (validated by interviews with subject matter experts) correctly classifies as empowered or not.

2. Index Sensitivity:

   Reflecting the sensitivity of the model, decides how much the empowerment score is affected by changes in particular indicators.

3. Model Comparability Score:

   It assesses how well the proposed model fits with field observations in relation to how well it matches existing models or how well it advances upon those models.

4. Empowerment Gain %:

   The empowerment index measures the relative increase in empowerment from before to after the microfinance intervention.

TABLE 6: ACCURACY OF EMPOWERMENT CLASSIFICATION

Participants (n)	Kabeer's Model	WEAI	EEI	LEI	Proposed Method
75	68%	70%	65%	72%	85%
150	69%	71%	67%	74%	86%
225	70%	72%	69%	75%	87%
300	71%	73%	71%	76%	88%

TABLE 7: INDEX SENSITIVITY

Participants (n)	Kabeer's Model	WEAI	EEI	LEI	Proposed Method
75	0.45	0.50	0.48	0.46	0.65
150	0.46	0.51	0.49	0.47	0.67
225	0.47	0.52	0.50	0.48	0.69
300	0.48	0.53	0.51	0.49	0.71

TABLE 8: MODEL COMPARABILITY SCORE

Participants (n)	Kabeer's Model	WEAI	EEI	LEI	Proposed Method
75	60%	62%	58%	61%	80%
150	61%	63%	59%	62%	81%
225	62%	64%	60%	63%	82%
300	63%	65%	61%	64%	83%

Table 9: Empowerment Gain %

Participants (n)	Kabeer's Model	WEAI	EEI	LEI	Proposed Method
75	8%	9%	7%	8%	20%

150	9%	10%	8%	9%	22%
225	10%	11%	9%	10%	24%
300	11%	12%	10%	11%	25%

A comparison of the Proposed Method with previously established models; Kabeer's model, WEAI, EEI, and LEI; reveals significant improvements in every one of the four performance criteria involved. For instance, the proposed method increases the Accuracy of Empowerment Classification from a maximum of 76% (LEI) to 88% (as indicated in Table 6). This implies a 12-15% rise in the capacity to accurately classify the empowerment status of the people. With a rise from 0.48 to 0.71, the proposed approach beats the present models by 18-20% in Index Sensitivity, a measure of how responsive the empowerment index is to changes in individual indicators (see Table 7 for further details). The Model Comparability Score indicates that the proposed method aligns with real-world observations by as much as 20% more. Rising from 64% (LEI) to 83% (Table 8), the score implies that the proposed method is more consistent with reality. Furthermore, notable improvement is seen in the Empowerment Gain%, which indicates the relative increase in empowerment after the intervention. Although the present models only show a maximum gain of 11% (Table 9), the proposed method gains as much as 25%.

VI. CONCLUSION

The proposed method provides a more consistent and robust framework for evaluating the impact microfinance has on women's empowerment during SHG participation. The method can detect more subtle changes in empowerment levels than the models now in use since it allocates weights using PCA and a composite Empowerment Index. Higher accuracy, sensitivity, comparability, and empowerment gain offer more evidence that the method properly shows the impact of microfinance projects in the real world.

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