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PRODUCTION FORECAST IN MSME USING MACROECONOMIC INPUT – AN ANFIS MODEL

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Abstract

Over the past few decades, the Micro, Small, and Medium Enterprises (MSMEs) sector has emerged as a dynamic and vibrant component of the economy of India. A pivotal role is being played by MSMEs to generate noteworthy prospects in employment with relatively lower capital investment compared to large industries, while also contributing to the development of rural and underdeveloped areas. Macroeconomics plays a central role in understanding the dynamics of national and global economies by analyzing aggregate indicators such as GDP (Gross Domestic Product), inflation, unemployment, and interest rates. This research attempts to predict the MSME production based on the Macroeconomic fuzzy input variables using the ANFIS (Adaptive Neuro Fuzzy Inference) model. The time series data, such as GDP Per Capita (at constant price), Repo Rate, CRR (Cash Reserve Ratio), and CPI (Consumer Price Index), are considered as macroeconomic input variables, and the output variable is MSME Production (at constant price) for the last 20 years. The paper compares the actual value of MSME production with the ANFIS outcome and the prediction accuracy of the output variable between the same membership function (MF) usage for all the input variables and different MF usage of the input variables, with a linear output MF being observed. The prediction accuracy obtained in the latter case overcomes the prediction accuracy of the former. Accurate prediction of MSME production volume using macroeconomic variables helps policymakers envision industrial activity and design sensible fiscal and monetary measures to alleviate growth and support the MSME sector.

Keywords: ANFIS, MSME, GDP, CRR, Repo Rate, CPI

I. Introduction

Micro, Small, and Medium Enterprises (MSMEs) are central to nurturing the development of the economy, engendering employment, and promoting innovation in both developing and developed countries. The significant diversity and inconsistency among official SME definitions have reached a point where it is essential to reconsider their formulation and application. (Gibson and Van der Vaart 2008). These enterprises are predominantly engaged in the production, processing, or safeguarding of goods and commodities. MSMEs are a significant sector in the Indian economy and have immensely supported the country's socio-economic development. In addition to the generation of employment opportunities, MSME also works hand-in-hand towards the expansion of the rural areas (www.lendingkart.com/msme-1oan/what-is-msme/). A strategic role has been played by the MSMEs in promoting the progress and development of khadi, coir, and village industries. In India, the impact of MSMEs is close to 8 per cent of the country's Gross Domestic Product (GDP), around 45 per cent of the outcome of the manufacturing sector, and approximately 40 per cent of the country's export (www.lendingkart.com/msme-1oan/what-is-msme/). Their capability to modernize rapidly gives them a noteworthy lead in contributing to the overall economy. However, MSMEs time and again surface noteworthy challenges, that comprises access to financing, market volatility, and fluctuating production levels driven by macroeconomic factors. Predicting production levels in MSMEs is therefore fundamental to ensuring their stability and long-term growth.

Adaptive Neuro-Fuzzy Inference Systems (ANFIS) stand as a powerful architecture for augmenting the precision and interpretability of financial modelling. Impeccably integrating the powers of fuzzy logic and artificial neural networks, ANFIS proves predominantly pertinent for managing the intricacy and ambiguity inherent in financial data. At its core, ANFIS employs a hybrid framework, conjoining fuzzy logic rule-based reasoning with the adaptive learning capabilities of neural networks. This integration enables financial analysts to cultivate models that are not just able to capture intricate patterns embedded in market data but also adapt to changes in environmental conditions over time. (Shing and Jang 1993). ANFIS has appeared as an encouraging hybrid model that conglomerates the learning proficiency of neural networks with the cognitive power of fuzzy logic systems (Uwimana 2024). ANFIS is a hybrid computing model that synthesizes the neural network and fuzzy logic, forming a robust framework adept at apprehending complex relationships within financial data (Petkovic et al. 2019). ANFIS can handle uncertainties intrinsic in economic data, making it well-suited for predicting complex components like MSME production, which is influenced by various macroeconomic factors. ANFIS is unique in its capability to incorporate both numerical and linguistic information, summarizing quantitative market data and qualitative, skilful information. The adaptive nature of ANFIS permits it to spontaneously adjust parameters in response to varying market conditions, an important feature for apprehending the vibrant nature of financial markets where abrupt changes, startling news, and global events can significantly impact trends. The neural network aspect of ANFIS adds to its ability to structure intricate non-linear relationships usually found in financial time series data (Melin et al. 2012). The ANFIS architecture characteristically comprises five layers, each aiding a distinct purpose in the modelling process.

Macroeconomic variables such as the Repo rate, Reverse Repo rate, Per Capita GDP, SLR, CRR, CPI, and Bank Rate can exhibit fuzziness due to a variety of factors. These reasons refer to the integral complexity and uncertainty in economic systems, where the associations between variables and their influence on the economy are often abstruse and context-dependent. The economy is predisposed by dynamic interactions between multiple actors, global factors, feedback mechanisms, and context-specific conditions. As a result, while these variables can be accurately measured, their elucidation and effects are often fuzzy, making fuzzy logic a useful tool for modelling and understanding them (Melin et al. 2012; Uwimana 2024). Some fundamental reasons for the fuzziness in Macroeconomic variables are attributed to the dynamic and unpredictable economic environment, such as global trade, political decisions, consumer confidence, etc. Varying sensitivity to different economic sectors like context specific interpretations, imperfect data and measurement, multiple conflicting interests of central banks and governments, global inter-dependencies like global trade, flows of resources, exchange rates, and other geopolitical events, policy disagreement among policymakers, economists, and financial analyst etc., are few reasons assigned to the fuzziness in Macroeconomic variables (Melin et al. 2012; Uwimana 2024). Macroeconomic variables such as inflation rate (CPI), Repo rates, GDP, and CRR significantly affect MSME production. However, the intricate associations amongst these elements and production levels are often difficult to assess using traditional linear models. In this aspect, the causal nexus of output by MSME, exports by MSME, total exports, and the GDP of the Indian economy has been scrutinized by Sahnewaz (2018). By integrating these variables into the ANFIS model, it is possible to create a robust prediction framework that improves decision-making for MSMEs, financial institutions, and policymakers.

The limited application of the Adaptive Neuro-Fuzzy Inference System (ANFIS) to macroeconomic variables represents a notable gap in the existing literature. While ANFIS has shown potential in various fields, including finance and engineering, its specific utilization in broadly addressing macroeconomic dynamics has been relatively meagre. Existing studies often focus on individual economic indicators, neglecting the holistic integration of multiple macroeconomic variables, such as growth of GDP, rate of interest, inflation, and exchange rates. In this aspect, a comprehensive systematic review and a bibliography on the topic of regression analysis in fuzzy environments have been studied by Chukhrova and Johannssen (2019). Melin et al. (2012) in their paper describe an architecture for ensembles ANFIS with emphasis on its application to the prediction of chaotic time series to minimize the prediction error. Jovic et al. (2018) investigated the exchange rate effect on GDP using ANFIS to predict GDP in relation to the exchange rate. Raharaja et al. (2021) analyzed the fuzzy membership functions to find out which one of them gives the best result in implementing the ANFIS method to predict the growth of inflation. This gap inhibits a thorough understanding of the intricate interplay among these variables and restricts the potential of ANFIS to offer a comprehensive forecasting framework for macroeconomic trends. Bridging this gap is crucial for advancing the application of ANFIS in economic research and gaining deeper insights into the complex relationships that drive macroeconomic dynamics (Uwimana 2024).

The current status of micro, small, and medium enterprises in the country has been studied by Khanna and Singh (2018). Rawat (2019) came up with the opinion that the MSME sector holds a crucial position in shaping India's economy, employing millions of people and contributing significantly to GDP. It has been examined by Reddy and

Sasidharan (2020) how the financial constraints of firms shape the global value chains participation of SMEs. The growth and contribution made by MSMEs in India in providing employment opportunities are studied by Siva Sree and Vasavi (2020). Behera et al. (2021) have attempted to quantify the impact of MSMEs on the Indian economy and the challenges and problems in the pre- and during COVID period. It is interpreted that the employment absorption capacity in the MSME sector has been high, followed by the other sectors, by Palaka and Das (2021). Shetty and Bhat (2022) came out with the strengths, weaknesses, opportunities, and challenges of the MSME sector. It is revealed by Gare (2022) that there is a continuous growth in the number of MSMEs units. The challenges of MSMEs in India, like financing, adequately skilled manpower, concurrent technology, market information, and demand forecast, export and domestic sales, have been studied by Patel and Tripathi (2022). However, there is very little research performed to discover the association of various Macroeconomic factors with the MSMEs' key performance indicators (KPIs) and vice versa, including both crisp and fuzzy variables of study. This paper emphasizes on the prediction of MSME production using macroeconomic input variables through the ANFIS model. The study seeks to explore how macroeconomic indicators influence MSME production levels and to evaluate the predictive capabilities of ANFIS in this context. By providing accurate forecasts, the model could offer valuable insights to stakeholders, helping them mitigate risks, optimize production, and improve strategic planning.

In the next section, the data used and its sources are described. Section 3 presents the methodology adopted for the paper. Section 4 talks about the results of the simulation and the discussions on it. Section 5 presents the Conclusion and future work.

II. Data and its Sources

In order to perform this research, the secondary data were collected from numerous sources from the year 2000 to 2023 for MSME production, Repo Rate, GDP, CPI, and CRR in India. This paper considers per capita GDP at constant prices as the real GDP of the economy. Also, GDP at constant prices is used to measure the actual value of a country's production. The main sources of the data are Reserve Bank of India's Data base on Indian Economy (www.rbi.org.in); Ministry of Micro, Small and Medium Enterprises (www.msme.gov.in); Development Commissioner Ministry of Micro, Small and Medium Enterprises (www.dcmsme.gov.in); National Small Industries Corporation (www.nsic.co.in); National Institute for Micro Small and Medium Enterprises (www.nimsme.org); Khadi and Village Industries Commission (www.kvic.org.in); Coir Board Ministry of MSME, Govt. of India (www.coirboard.gov.in); Mahatma Gandhi Institute for Rural Industrialization, Ministry of Micro, Small and Medium Enterprises (www.mgiri.org); NSE India, National Stock Exchange (www.nseindia.com); Ministry of Statistics and Programme Implementation (www.mospi.gov.in)

II. Methodology

The data set is obtained from the time series data of the last 20 years from different sources. Factor analysis is done with all the independent macroeconomic variables so as to explore the possibility of diminishing the number of interrelated variables and to simplify the complex data. The correlation matrix was built to find out the multicollinearity among independent variables. The relationship between MSME

Production in India with Macroeconomic variables like Repo rate, GDP, CRR, and CPI is built up by Fuzzy Regression analysis using Adaptive Neuro Fuzzy Inference System (ANFIS). The training of the dataset is done using a different number of epochs using the combination of Triangular, Trapezoidal, Gaussian, and mixed models while trying to fuzzify all the input variables and linear MF for the output variable. All the models were compared for the prediction accuracy for actual MSME production with the ANFIS outcome, and subsequently, the best model was chosen here.

ANFIS architecture and basic aspects of ANFIS

This section discusses the basic architecture of ANFIS and the algorithm used in the hybrid learning method in the ANFIS model.

Mathematical Modeling for ANFIS

Layer 1: Fuzzification Layer: This layer consists of the adaptive node having a node function, and the output is as follows:

$O_{1,i} = \mu_{Ai}(x),$ for $i=1,2\ldots81$ or

$O_{1,i} = \mu_{Bi}(y),$ for $i=1,2\ldots81$ or

$O_{1,i} = \mu_{Ci}(z),$ for $i=1,2\ldots81$ or

$O_{1,i} = \mu_{Di}(u),$ for $i=1,2\ldots81$

Where x, y, z and u is the input to the node i, in our case x, y, z and u represents Repo Rate, CPI, CRR and Per Capita GDP (at Constant Price) and A_i, B_i, C_i or D_i is a linguistic level (such as 'small', 'medium', 'large' or 'very large') associated with the node. Fuzzy set A (Ai, Bi, Ci, or Di) has the membership grade $O_{1,i}$ that signifies the extent to which the specified input x, y, z, and u satisfies the quantifier A.

Triangular Membership Functions are used for Repo Rate and CRR to represent the fuzziness in them. The triangular MF implementation function is as below:

$$f(x) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ \dfrac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases}$$

In Figure 1, the parameters a and c set the left and right feet or base points of the triangle, and the parameter b sets the position of the triangle peak. x is the magnitude of the input variable (Repo Rate and CRR) for calculating the membership value.

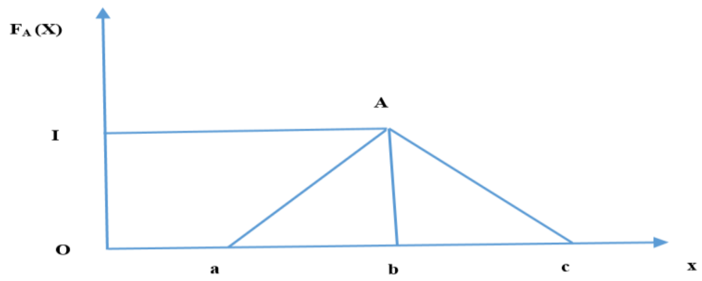


Fig. 1. Triangular Fuzzy Membership Function

Source: The authors.

For CPI and per capita GDP and constant price, Trapezoidal membership functions are considered to represent the fuzziness in them. The trapezoidal MF implementation function is as below:

$$f(x) = \begin{cases} 0, & (x < a)\ or\ (x > d) \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \frac{d-x}{d-c}, & c \le x \le d \end{cases}$$

Figure 2 shows that the parameters are defined by a lower limit a, an upper limit d, a lower support limit b, and an upper support limit c, where a<b<c<d and x is the value of the input variable (CPI and Per capita GDP) for calculating the membership value.

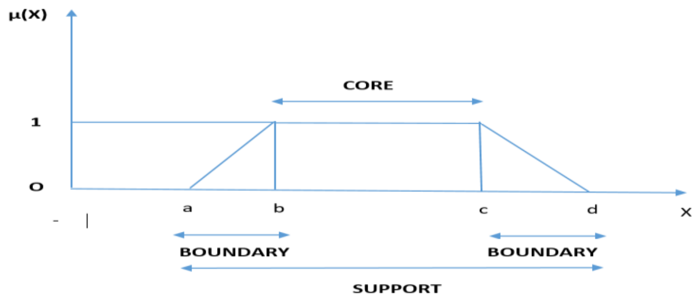


Fig. 2. Trapezoidal Fuzzy Membership Function

Source: The authors.

Layer 2: Product Layer: Every node in the product layer is a fixed node characterized by ANFIS, whose output is calculated using the product of all the incoming signals:

$$w1 = \mu A1(x)\ X\ \mu B1(y)\mu C1(y)\mu D1(u)$$
$$w2 = \mu A2(x)\ X\ \mu B2(y)\mu C2(z)\mu D2(u)$$
$$\dots$$
$$wi = \mu Ai(x)\ X\ \mu Bi(y)\mu Ci(z)\mu Di(u)$$

Layer 3: Normalized Layer: All the nodes in the Normalized layer are fixed nodes labeled N. The i-th node computes the proportion of the firing strength of the i-th rule to the firing strengths of all rules:

$$\bar{w}_1 = \frac{w1}{w1 + w2 + \cdots + wi}$$
$$\bar{w}_2 = \frac{w2}{w1 + w2 + \cdots + wi}$$
$$\cdots$$
$$\bar{w}_{\mathrm{i}} = \frac{wi}{w1 + w2 + \cdots + wi}$$

Layer 4: Defuzzification Layer: Every node residing in this layer is an adaptive node, and the node function of each is as follows:

$f1 = \bar{w}_1$ x $(p_1x+q_1y+r_1z+s_1y+t_1)$

$f2 = \bar{w}_2$ x $(p_2x+q_2y+r_2z+s_2y+t_2)$

...

$fi = \bar{w}_i$ x $(p_ix+q_iy+r_iz+s_iy+t_i)$

Where ANFIS utilizes the normalized firing strength from layer 3, with the parameter set of this node represented as (p_i, q_i, r_i, s_i, t_i). In the defuzzification layer, the parameters are known as consequent parameters.

Layer 5: Output Layer: The single node in this layer is a fixed node labelled ANFIS, which computes the overall output as the summation of all incoming signals.

$$f = f1 + f2 + \cdots . + fi$$

Number of Fuzzy Rules = $(Number\ of\ Membership\ Functions)^{Number\ of\ Inputs}$

In this research, the number of MFs has been taken as 3 for each independent variable, and the number of independent variables are four (Repo Rate, CPI, CRR, Per Capita GDP at constant price, respectively). Hence, the number of fuzzy rules are $3^4 = 81$.

Premise Parameters = (a_i, b_i, c_i, d_i)

Consequent Parameters = $(p_i, q_i, r_i, s_i, t_i)$

(a_i, b_i, c_i, d_i) -> Governing the slope of the Membership Function

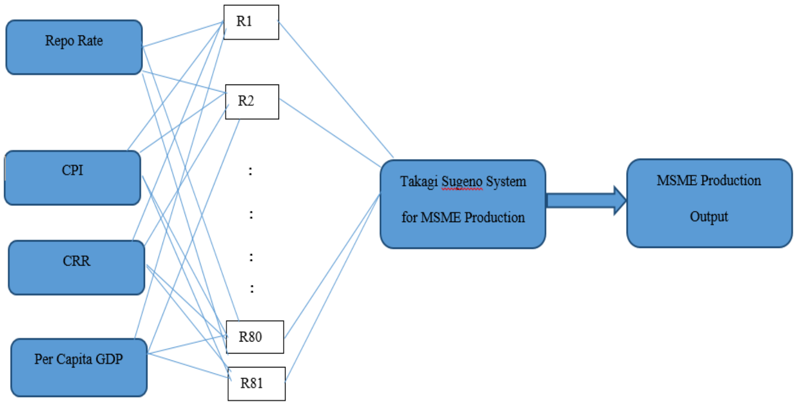


Fig. 3. A four-input first-order Takagi-Sugeno Fuzzy Model with eighty-one rules for the prediction of MSME production

Source: The authors.

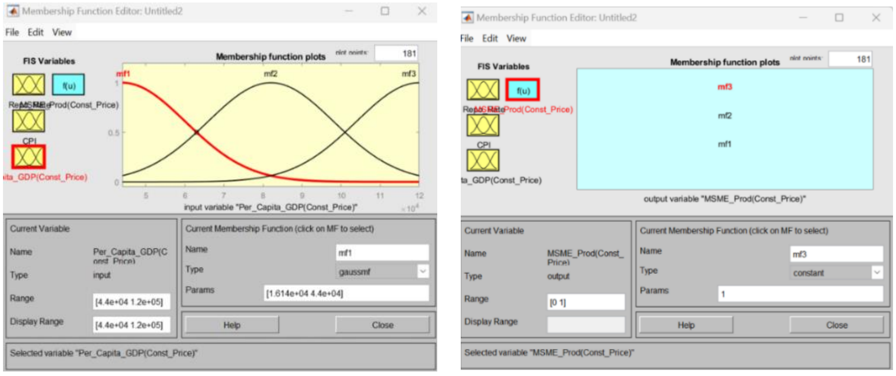
Figure 3 graphically shows the four-input first-order Takagi-Sugeno Fuzzy model with the input variables as Repo Rate, CPI, CRR, and Per Capita GDP. There are eighty-one rules (R1, R2, R3… till R81) that have been defined for the prediction of MSME production value.

IV. Results and Discussions

The computer program was performed on MATLAB (Version R2024b, The MathWorks Inc., USA) environment using Fuzzy Toolbox. ANFIS topologies with different input membership functions (Triangular, Trapezoidal, Gaussian, and Mixed) were trained. The figures below (Figures 4 to 12) show the outcome of using various membership functions against each independent variable. The related outcome of test scenarios is also depicted in the respective tables (Table-1 and 2). Factor analysis was done using IBM SPSS Statistics version 20. Multicollinearity using the variance inflation factor is done in Microsoft Excel software. Unit root test (Augmented Dickey-Fuller) and transformation of series using differencing is performed using R Studio Software version 2025.05.1+513.

Outcome of Model on Gaussian Membership Function:

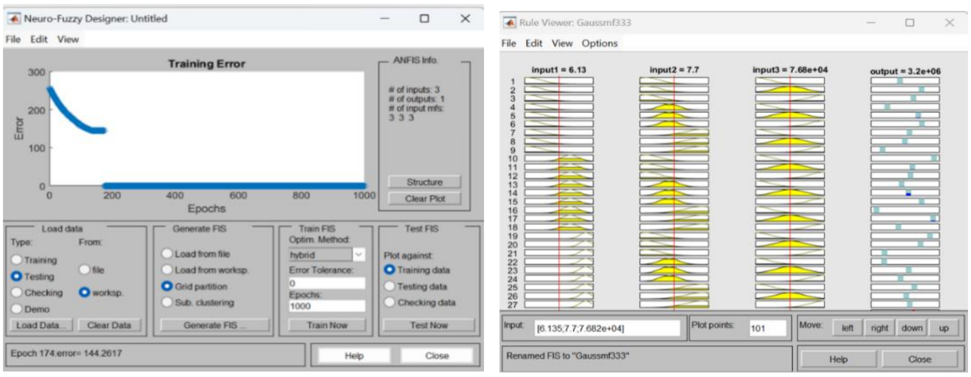
In this model, Gaussian MF has been used to represent the fuzziness of Repo Rate, CPI, and Per Capita GDP (at constant price), and for the MSME production (output variable), constant type MF is used.



(a) (b)

Fig. 4. (a) Gaussian Membership function for Input variable Per Capita GDP (Constant Price); (b) Output Variable MSME Prod (Constant Price)

Source: The authors.



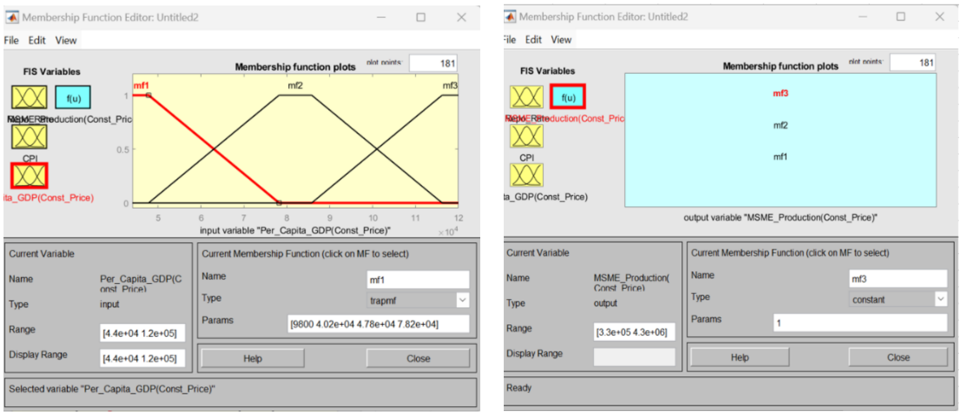
(a) (b)

Fig. 5. (a) Neuro Fuzzy Designer Training outcome; (b) Fuzzy Rule Viewer

Source: The authors.

Outcome of Model on Trapezoidal Membership Function:

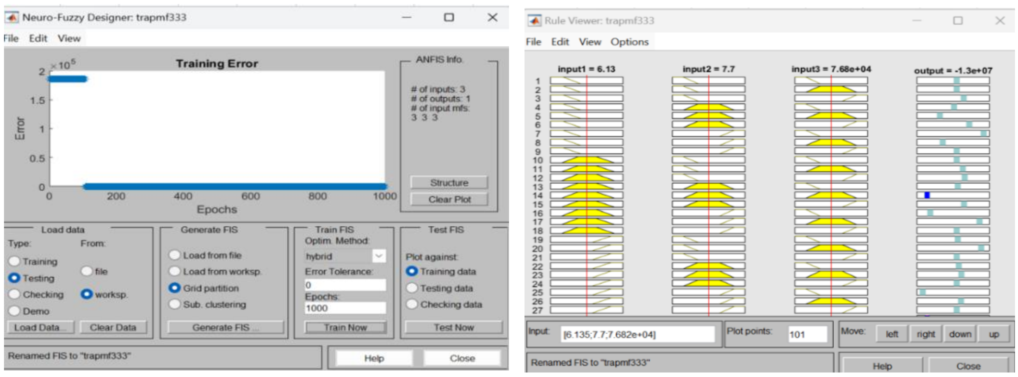
In this model, Trapezoidal MF has been used to represent the fuzziness of Repo Rate, CPI, and Per Capita GDP (at constant price), and for the MSME production (output variable), constant type MF is used.



(a) (b)

Fig. 6. (a) Trapezoidal MF for Input Variable Per Capita GDP (Constant Price); (b) Constant MF for Output Variable MSME Prod (Constant Price)

Source: The authors.



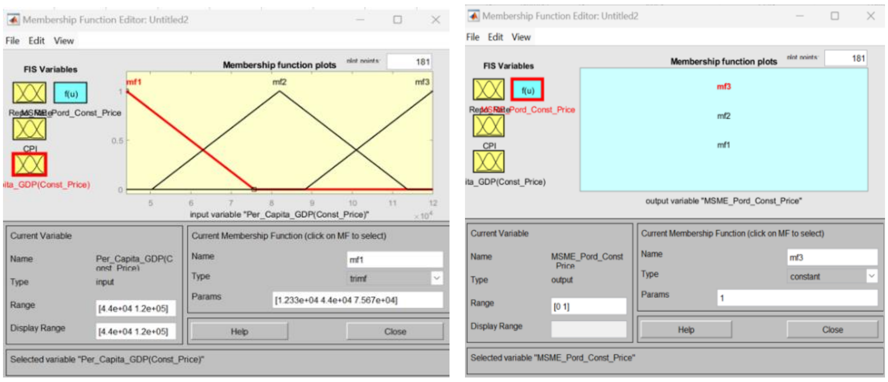
(a) (b)

Fig. 7. (a) Neuro Fuzzy Designer – Training Outcome; (b) Fuzzy Rule Viewer

Source: The authors.

Outcome of Model on Triangular Membership Function:

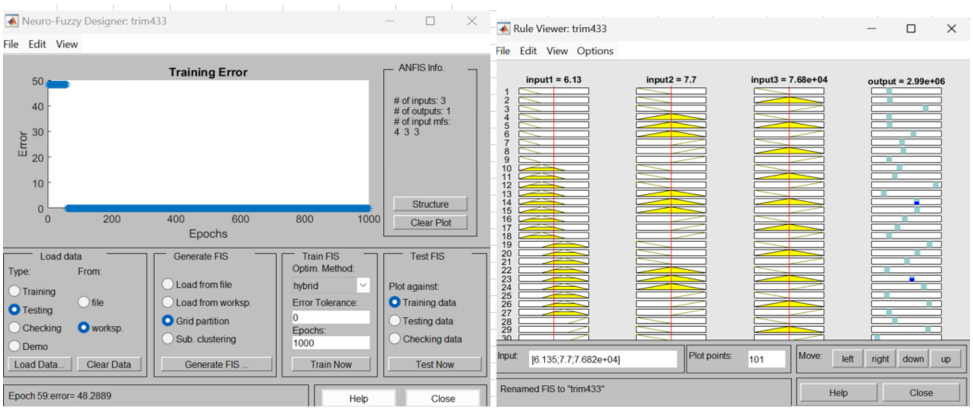
In this model, Triangular MF has been used to represent the fuzziness of Repo Rate, CPI, and Per Capita GDP (at constant price), and for the MSME production (output variable), constant type MF is used.



(a) (b)

Fig. 8. (a) Triangular Membership Function for Input Variable per Capita GDP (Constant Price); (b) Constant Membership Function for Output variable MSME Prod (Constant Price)

Source: The authors.



(a) (b)

Fig. 9. (a) Neuro Fuzzy Designer: Training Outcome; (b) Fuzzy Rule Viewer

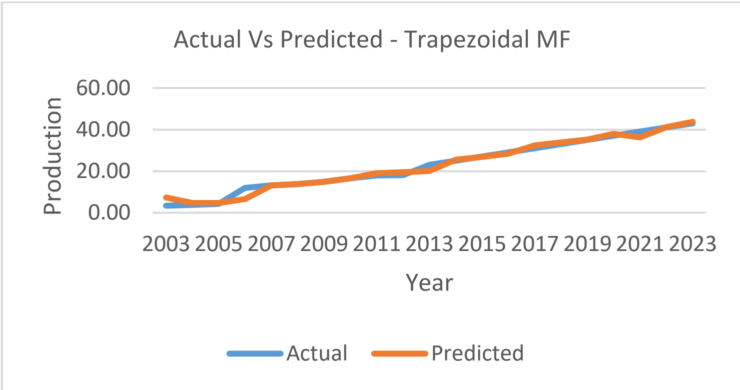
Source: The authors.

Table 1: Comparison of Results of ANFIS Prediction based on 3 different Fuzzy Membership Models.

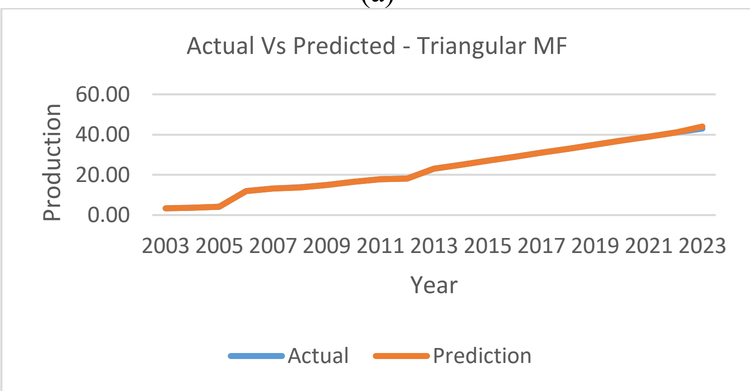
Year	Repo Rate (%)	CPI (%)	Per Capita GDP(At Constant Price-Rs Crore)	MSME Production(At Constant Price-Rs Crore)	ANFIS Outcome(At Constant Price-Rs Crore)	Type of MF	Error(Absolute Deviation)	% Prediction Error
2023	6.50	5.66	115746	4297337	4373937	Trapezoidal	76600	1.78
2023	6.50	5.66	115746	4297337	4401413	Triangular	104076	2.42
2023	6.50	5.66	115746	4297337	4401398	Gaussian	104061	2.42

Source: The authors.

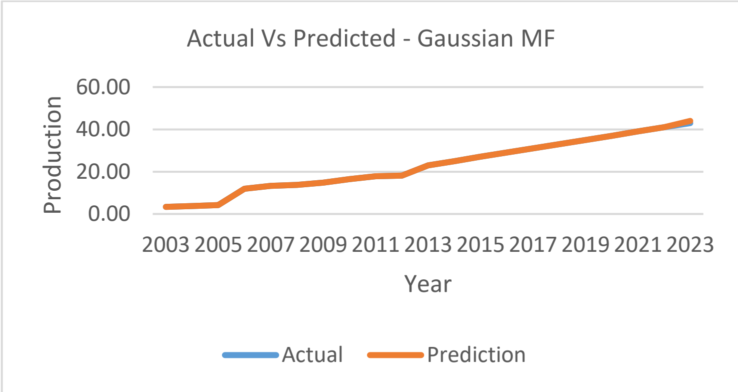
The above result shows that the Trapezoidal MF in the ANFIS prediction model gives the minimum percentage of prediction error (1.78 per cent) amongst all three MFs (Trapezoidal, Triangular, and Gaussian). The trapezoidal membership function offers enriched prediction accuracy as it effectively epitomizes unwavering ranges of macroeconomic variables such as GDP, Repo Rate, and CPI, where MSME production reactions remain relatively constant. Its flat tableland region condenses sensitivity to minor variations in economic indicators, permitting the ANFIS model to arrest wider economic rules more robustly. Furthermore, the trapezoidal shape provisions improved simplification of fuzzy rules and mirror threshold-type economic properties, thus augmenting the steadiness and trustworthiness of MSME production conjectures compared to triangular and Gaussian membership functions.



(a)



(b)



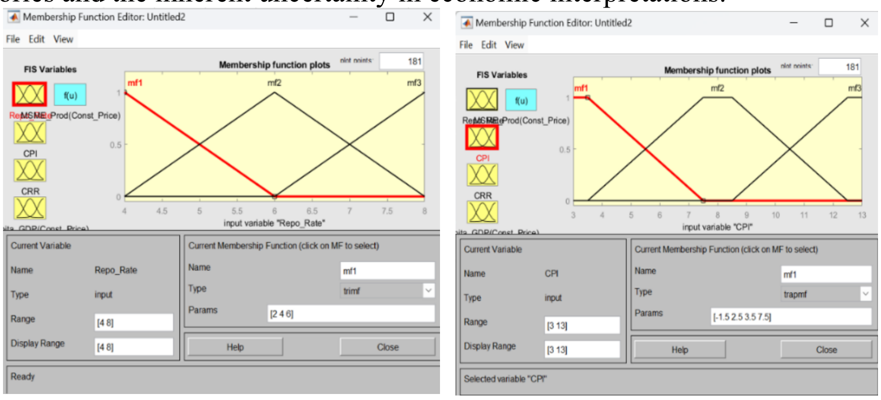
(c)

Fig. 10. (a) Actual Vs Predicted Production – Trapezoidal MF; (b) Triangular MF; (c) Gaussian MF

Source: The authors.

Outcome of the Mixed Model:

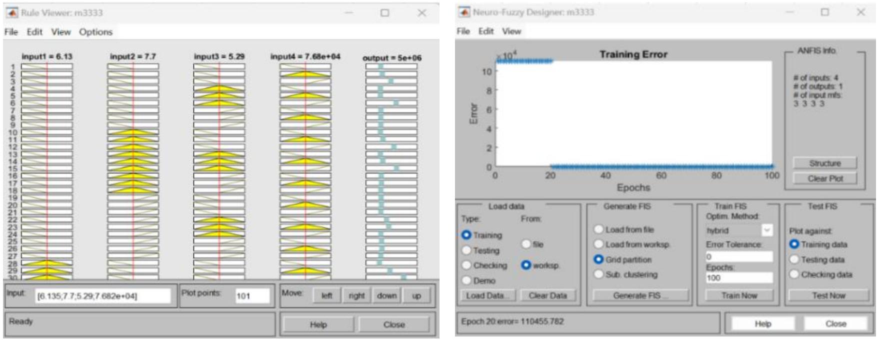
A mixed model consists of Triangular MF for Repo Rate and CRR; Trapezoidal MF for CPI, and Per Capita GDP (Constant Price) has been introduced to envisage the MSME Production (Constant Price). The Triangular Membership Function is the best suited for modelling the fuzziness of the repo rate and CRR, as these functions can effectively capture the gradual transitions and uncertainty between different repo rate and CRR categories. A triangular function works well for capturing a clear peak (optimal repo rate or CRR) with smooth transitions. Triangular models handle the vagueness in policy outcomes and economic effects of small rate changes. The Trapezoidal Membership Functions are the most appropriate for modelling the fuzziness of GDP and CPI as they can account for gradual transitions between categories and the inherent uncertainty in economic interpretations.



(a) (b)

Fig. 11. (a) Triangular Membership Function for Input Variable Repo Rate; (b) Trapezoidal Membership Function for Input Variable CPI

Source: The authors.



(a) (b)

Fig. 12. (a) Fuzzy Rule viewer; (b) Neuro Fuzzy Designer: Training Outcome

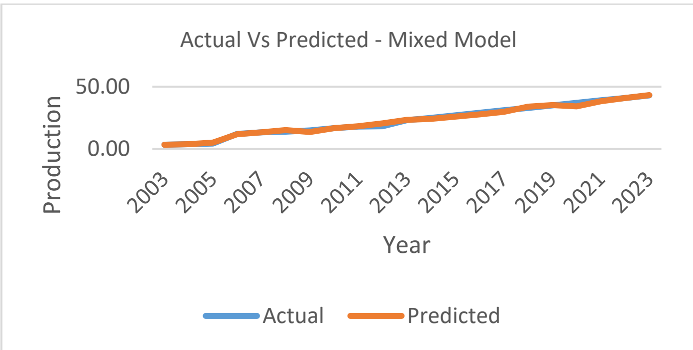
Source: The authors.

Table 2 : Results of Fuzzy Membership Mixed Model.

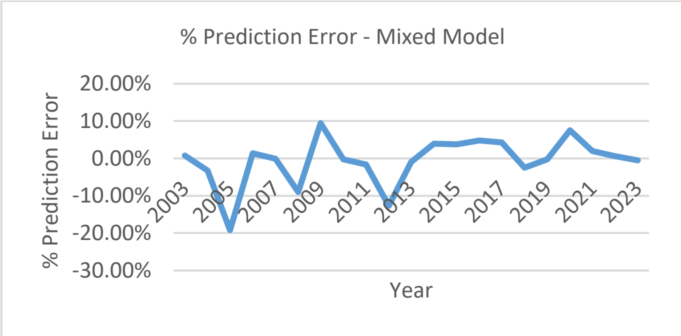
Year	Repo Rate (%)	CPI (%)	CRR (%)	Per Capita GDP (Constant Price -Rs Crore)	MSME Production (At constant Price-Rs Crore)	ANFIS Outcome-MSME Prod(At constant price)	Absolute Deviation	% Prediction Error	Model
2023	6.50	5.66	3.75	115746	4297337	4319226	21888	0.51	Mixed

Source: The authors.

The above result shows that the Mixed model MF in ANFIS gives further better accuracy (prediction error 0.51 per cent) while predicting the MSME production value at constant price. The mixed membership function model improves prediction accuracy by considering different macroeconomic variables to be characterized using the most appropriate membership shapes. This method enhances the suppleness of the ANFIS model to accommodate varied statistical designs and nonlinear associations among GDP, Repo Rate, CRR, and CPI. By spawning more adaptive fuzzy partitions and rules, the mixed MF structure lessens modelling bias and expands the steadiness and meticulousness of MSME production forecasts compared to single-type membership functions. Figure 13 below shows the Actual Vs. Predicted MSME production values and percentage of prediction error for the Mixed Fuzzy model with the last 20 years of time series data.



(a)



(b)

Fig. 13. (a) Actual Vs. Predicted Production – Mixed Model; (b) per cent Prediction Error – Mixed Model

Source: The authors.

Factor analysis results with KMO and Bartlett's test outcome, and the multicollinearity results using Variable Inflation Factor (VIF) are shown in Tables 3 and 4 below. The outcome of the KMO sampling adequacy is 0.548. The KMO measures should be more than 0.7 to apply the factor analysis technique; hence, the factor scores were not considered for reconstructing the ANFIS model subsequently.

Table 3: Results of KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.548
Bartlett's Test of Sphericity	Approx. Chi-Square	88.843
	df	21
	Sig.	.000

Source: The authors.

Table 4: Results of Multicollinearity using VIF.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	6401513.244	3197614.433		2.002	.067		
	Bank Rate	59004.647	43997.339	.160	1.341	.203	.382	2.616
	Repo Rate	-101413.857	188735.757	-.087	-.537	.600	.208	4.806
	Reverse_ Repo_ Rate	128124.914	164381.623	.102	.779	.450	.316	3.162
	GDP	2.676	1.292	.452	2.072	.059	.114	8.734
	CRR	182314.267	122081.228	.156	1.493	.159	.499	2.004
	SLR	-287773.543	145518.557	-.556	-1.978	.070	.069	14.493
	CPI	33954.421	62595.413	.063	.542	.597	.402	2.490

a. Dependent Variable: MSME_Prod

Source: The authors.

Unit root test (ADF) was performed on GDP, CPI, Repo Rate, and CRR. ADF test results at 5% level of significance show that the p-value of CRR is less than 0.05, which concludes that the CRR time series data is stationary. However, for Repo Rate, GDP, and CPI, the p-value came as more than 0.05; hence, it was concluded that Repo Rate, GDP, and CPI are non-stationary time series data. In this scenario, using a mixture of original and differenced independent variables while performing prediction through an ANFIS model is avoided as it brings several problems like incompatible data scales, impaired interpretation of fuzzy rules, reduced predictive accuracy, and challenges the structure of the ANFIS model.

An accurate forecast of MSME production using macroeconomic variables such as GDP, Repo Rate, CRR, and CPI supports policymakers in envisioning industrial output trends and designing timely economic and financial policies. It permits superior planning of credit support, employment generation, and resource allocation for the MSME sector. Such forecasts also help governments in upbeat budgetary planning and alleviating the larger industrial ecosystem.

V. Conclusions

It can be concluded that Repo Rate, GDP, CRR, and CPI are independently contributing to the MSME production outcome in a positive way. The macroeconomic variables like Bank Rate, Reverse Repo Rate, and Statutory Liquidity Ratio (SLR) are correlated to each other and can be eliminated while predicting the MSME production outcome. The research results outcome indicates that while framing the ANFIS model to forecast the MSME production, if a mixed membership function is used, choosing Trapezoidal MF for GDP and inflation (CPI) and Triangular MF for Repo Rate and CRR, and linear MF for the output variable MSME Production, the model produces the best prediction for the MSME production outcome with an error in prediction of 0.51 per cent while predicting the 2023 MSME production value. The ANFIS model also helps to augment the accuracy of the prediction of MSME production based on macroeconomic time series input variables, taking into consideration the complexity and uncertainty inherent in financial data. Precise MSME production forecasts enable the government to forestall employment demand, frame proactive labor and skill development policies, and launch a quantitative footing for active budgetary planning.

As future work, one can consider exploring predicting further on MSME production for future years based on some other mixed models after assigning Gaussian MFs to some of the input variables like GDP, Inflation, and Triangular/ Trapezoidal MFs for Repo Rate and CRR to see for any further prediction accuracy possibilities. The outcomes obtained from these results can be utilized to develop policies for determining the appropriate membership functions to represent the fuzziness of macroeconomic independent variables, enabling improved accuracy in predicting MSME production. This is essential for managing overall growth, employment, and performance of industries.

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Conflict of Interest:

The authors declare no conflicts of interest regarding this paper.

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