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## FUZZY MODELS FOR PREDICTING INFLATION AND ECONOMIC GROWTH

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### **Abstract**

The accurate prediction of inflation and economic growth remains a crucial challenge for economists and policymakers due to the complex, nonlinear, and uncertain nature of macroeconomic systems. Traditional statistical and econometric models often fail to fully capture these dynamics, especially under conditions of ambiguity and incomplete information. This study explores the application of fuzzy models, grounded in fuzzy set theory and fuzzy inference systems, as an effective alternative for forecasting inflation and economic growth. Fuzzy logic offers the advantage of handling imprecise data and linguistic variables such as “high inflation” or “moderate growth,” thereby providing flexible, human-like reasoning in uncertain environments. By integrating expert knowledge with computational techniques, fuzzy models demonstrate potential to outperform conventional methods in terms of adaptability and reliability. The findings of this research are expected to contribute to economic forecasting literature while offering policymakers and financial institutions more robust tools for informed decision-making.

**Keywords:** Fuzzy logic, Inflation prediction, Economic growth, Forecasting models, Uncertainty handling

### **Introduction**

The prediction of inflation and economic growth has long been a central concern of economists, policymakers, and financial institutions, as these two indicators play a vital role in shaping monetary policies, investment decisions, and long-term development strategies. Traditional forecasting approaches such as regression analysis, ARIMA models, and econometric simulations have contributed significantly to understanding macroeconomic dynamics, but they often fall short in handling the inherent uncertainty, vagueness, and nonlinearity present in economic data. Inflation, influenced by diverse factors such as demand-supply imbalances, monetary policies, global oil prices, and fiscal interventions, does not always follow predictable patterns, while economic growth is shaped by a complex interplay of structural, institutional,

and global forces. In this context, fuzzy logic provides a powerful alternative by incorporating uncertainty and imprecision into the modeling process, thus enabling more flexible, human-like reasoning in decision-making. Fuzzy models, built on the principles of fuzzy sets and fuzzy inference systems, allow the incorporation of expert knowledge in linguistic terms such as “high inflation,” “moderate growth,” or “low demand,” which cannot be precisely defined by crisp mathematical values. This capacity makes fuzzy models particularly suitable for addressing macroeconomic forecasting problems where incomplete information and ambiguous patterns are common. Moreover, fuzzy models have the advantage of integrating with other computational techniques, including artificial neural networks and genetic algorithms, to produce hybrid models with enhanced accuracy and adaptability. Recent research demonstrates that fuzzy systems can outperform traditional models in capturing nonlinear and dynamic relationships between economic variables, offering insights that are both quantitative and qualitative. By applying fuzzy models to inflation and growth prediction, this research aims to fill an important gap in the existing literature, where fuzzy approaches remain underutilized compared to other domains like engineering and control systems. The study is expected to provide not only methodological contributions to economic forecasting but also practical implications for policymakers and investors seeking reliable, flexible, and adaptive prediction tools. Ultimately, the application of fuzzy logic in this domain highlights the importance of interdisciplinary approaches in economics, opening new avenues for research and offering robust frameworks to tackle the complexities of global and national economic environments.

### **Significance of the Study**

The significance of this study lies in its potential to enhance the accuracy and reliability of forecasting inflation and economic growth, two of the most critical indicators guiding monetary policy, fiscal planning, and investment decisions. Traditional econometric and statistical models often face limitations in capturing the nonlinear, dynamic, and uncertain behavior of economic variables, leading to gaps in predictive power. By applying fuzzy models, this research introduces a methodological innovation that can effectively handle ambiguity, imprecise data, and complex interdependencies, thereby offering more flexible and adaptive forecasting mechanisms. The study contributes to the academic literature by expanding the application of fuzzy logic within the field of economics, where its use remains limited compared to engineering and control sciences. Practically, the findings will provide policymakers, central banks, and financial institutions with robust decision-support tools, enabling them to design more effective strategies for economic stability, sustainable growth, and inflation management.

### **Scope of the Study**

The scope of this study focuses on exploring the applicability of fuzzy models in predicting inflation and economic growth by addressing the challenges of uncertainty, vagueness, and complexity inherent in macroeconomic systems. The research is limited to analyzing key economic indicators such as consumer price index, interest rates, fiscal policies, and GDP growth trends within a defined geographical and temporal context, which may include national-level data or selected regions depending on data availability. While the study emphasizes the use of fuzzy logic as the primary methodological framework, it also considers the potential for hybrid approaches that integrate fuzzy systems with other computational techniques like neural networks or econometric models. The investigation is not intended to provide country-specific policy prescriptions but rather to evaluate the general effectiveness of fuzzy models in macroeconomic forecasting. This ensures broader applicability, while acknowledging limitations related to data quality, model generalization, and computational complexity.

### **Overview of Global and National Economic Challenges**

The global and national economies are increasingly confronted with multifaceted challenges that hinder sustainable growth and stability, making the task of accurate forecasting ever more critical. On a global scale, persistent inflationary pressures, rising energy prices, and disruptions in supply chains due to geopolitical tensions and pandemics have created significant volatility in markets. Climate change, technological disruptions, and shifting trade dynamics further add to the unpredictability of economic performance. Inflation, often driven by fluctuating oil prices, currency depreciation, or monetary policy shifts, directly affects purchasing power and investment decisions, thereby complicating growth trajectories. At the national level, countries grapple with challenges such as unemployment, fiscal deficits, uneven income distribution, and structural bottlenecks in production and infrastructure. Developing nations, in particular, face the dual burden of managing inflation while striving for inclusive growth, often constrained by limited resources and external vulnerabilities. Meanwhile, advanced economies encounter issues of stagnant productivity, aging populations, and debt sustainability. Both global and national economies are increasingly interconnected, meaning that shocks in one region—whether financial crises, natural disasters, or political instability—quickly transmit across borders, intensifying risks and uncertainties. These challenges underscore the limitations of traditional economic models that rely heavily on precise, stable data and linear assumptions, which are often unrealistic in today's dynamic environment. Consequently, there is a pressing need for innovative approaches such as fuzzy models that can capture uncertainty, accommodate incomplete information, and provide more flexible and adaptive forecasting mechanisms to help policymakers and institutions navigate these complex economic realities.

### **Importance of Inflation and Economic Growth as Macroeconomic Indicators**

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Inflation and economic growth are among the most significant macroeconomic indicators used to measure the health and performance of an economy, making them essential tools for policymakers, researchers, and investors alike. Inflation, generally measured through the consumer price index (CPI) or wholesale price index (WPI), reflects changes in the purchasing power of money and directly influences living standards, wage adjustments, and monetary policy decisions. High inflation erodes the value of savings, reduces investment incentives, and creates instability in markets, while very low or negative inflation can lead to stagnation and weak demand. On the other hand, economic growth, usually represented by gross domestic product (GDP), indicates the overall expansion of productive capacity, job creation, and improvements in social welfare. Sustained growth is vital for reducing poverty, generating employment, and financing public infrastructure and services. The interaction between these two indicators is also critical: moderate inflation often accompanies economic growth, while excessive inflation or deflation can distort growth patterns. Policymakers rely on accurate forecasts of both indicators to design effective fiscal and monetary strategies, balance demand and supply, and maintain stability in the economy. For businesses and investors, these indicators provide guidance for strategic planning, investment decisions, and risk management. Thus, inflation and economic growth not only serve as benchmarks for assessing economic performance but also act as vital signals for future trends, making their accurate prediction indispensable in ensuring sustainable development and long-term economic stability.

### **Advantages of Fuzzy Systems over Traditional Statistical/Econometric Models**

Fuzzy systems offer several distinct advantages over traditional statistical and econometric models, particularly in the context of forecasting complex and uncertain phenomena such as inflation and economic growth. Traditional models like regression analysis, ARIMA, or econometric simulations are grounded in precise numerical data, rigid assumptions, and linear relationships, which often limit their effectiveness in capturing the nonlinear, dynamic, and ambiguous behavior of macroeconomic systems. In contrast, fuzzy systems are designed to handle uncertainty, vagueness, and incomplete information, making them more adaptable to real-world situations where exact values are difficult to obtain. One of the most important advantages of fuzzy systems is their ability to incorporate human expertise through linguistic rules, such as “high inflation,” “moderate growth,” or “low demand,” which cannot be easily quantified in conventional models. This human-like reasoning allows fuzzy models to bridge the gap between quantitative data and qualitative knowledge, offering richer insights. Furthermore, fuzzy systems are inherently flexible and capable of modeling nonlinear relationships without requiring strict statistical assumptions, which makes them more robust when data is noisy, imprecise, or limited. Unlike econometric models that often struggle with

multicollinearity, parameter estimation, or structural breaks, fuzzy systems can accommodate such complexities with relative ease. They are also well-suited for integration with other computational techniques such as neural networks, genetic algorithms, and machine learning methods, resulting in powerful hybrid models that combine adaptability with predictive accuracy. Another advantage lies in their transparency and interpretability; fuzzy models can explain the reasoning process behind predictions in a rule-based framework, which is often lacking in black-box approaches like deep learning. This interpretability is particularly valuable in economics, where policymakers and stakeholders require not only accurate forecasts but also understandable justifications for decision-making. Overall, fuzzy systems provide a versatile, reliable, and human-centric approach to economic forecasting, offering improved adaptability, better handling of uncertainty, and enhanced explanatory power compared to traditional statistical and econometric methods.

### **Literature Review**

**Hašková (2019).** The study emphasizes that GDP growth is influenced by a wide range of uncertain and interdependent factors, making traditional linear models inadequate for capturing its dynamic nature. By applying fuzzy logic, the model incorporates linguistic terms such as “low,” “moderate,” or “high” growth, thus allowing for a more realistic representation of economic conditions. Hašková demonstrates that fuzzy systems provide greater flexibility in handling incomplete and imprecise information, particularly in situations where economic indicators fluctuate unpredictably due to global shocks or structural changes. The study concludes that fuzzy prediction models can improve forecasting accuracy, enhance decision-making for policymakers, and serve as a valuable complement to traditional methods. This contribution is significant because it extends the application of fuzzy logic to macroeconomic forecasting, an area where such approaches have been relatively underutilized compared to engineering and control sciences.

**Enke and Mehdiyev (2014).** The authors argue that inflation dynamics are highly nonlinear and influenced by multiple interrelated variables, making conventional econometric approaches insufficient. By integrating fuzzy systems, which manage uncertainty and imprecision, with neural networks, which provide adaptive learning and pattern recognition, the hybrid model achieves superior forecasting performance. The study uses empirical data to compare results with standard models and finds that the neuro-fuzzy approach delivers lower prediction errors and higher reliability. One of the key contributions is the interpretability of fuzzy logic, which provides understandable rule-based reasoning, while neural networks enhance adaptability to changing economic conditions. The model is particularly effective in capturing unexpected shifts in inflation trends, making it relevant for policymakers and financial analysts. Overall, this study demonstrates the potential of hybrid intelligent systems in macroeconomic

forecasting, highlighting their ability to balance interpretability with predictive power, a challenge often faced in the application of advanced computational methods in economics.

**Korol (2014).** Traditional statistical models often struggle with the unpredictability of exchange rate movements, as they rely on precise input data and linear assumptions that rarely reflect real-world conditions. Korol’s fuzzy logic model addresses these limitations by incorporating linguistic variables such as “appreciation,” “stability,” or “depreciation” to describe exchange rate behaviors. The model successfully captures nonlinear relationships and the imprecise nature of currency fluctuations, offering more reliable forecasts than conventional methods. By validating the approach with empirical data, the study demonstrates that fuzzy systems can reduce forecasting errors and provide more meaningful insights into exchange rate dynamics. Since exchange rates play a critical role in determining inflation levels and economic growth, this research provides valuable implications for monetary policy, trade planning, and investment strategies. Korol’s work highlights the effectiveness of fuzzy logic in managing uncertainty in financial forecasting and reinforces the importance of interdisciplinary methods in economics.

**Sari et al. (2017).** Recognizing that inflation is influenced not only by domestic monetary and fiscal policies but also by global factors such as commodity prices, currency movements, and international shocks, the study integrates these external elements into the forecasting framework. The fuzzy neural system combines fuzzy logic, which handles ambiguity and imprecision, with neural networks, which learn patterns and adapt to complex relationships. This hybrid approach provides greater flexibility in modeling inflation’s nonlinear dynamics and enhances predictive accuracy compared to conventional econometric models. The results show that including external factors significantly improves robustness, making forecasts more reliable for policy planning. The study also underscores the adaptability of fuzzy-based systems in dealing with multidimensional and uncertain economic environments. Overall, this research contributes to inflation forecasting literature by emphasizing the importance of hybrid models and the inclusion of external influences, thereby offering practical tools for policymakers facing dynamic global economic conditions.

**Raharja et al. (2021).** ANFIS combines the reasoning capability of fuzzy logic with the learning ability of neural networks, making it particularly suitable for forecasting tasks in uncertain and nonlinear environments. The study specifically analyzes how different types of membership functions—such as triangular, trapezoidal, and Gaussian—affect the accuracy and reliability of inflation predictions. By conducting experiments with various function designs, the authors demonstrate that the choice and configuration of membership functions significantly influence the performance of the ANFIS model. Their findings suggest that well-structured membership functions improve the model’s precision, reduce forecasting errors, and enhance its adaptability to changing economic conditions. The study provides practical insights for

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researchers and practitioners by highlighting the critical design considerations in building effective fuzzy-neural hybrid systems. In the context of inflation forecasting, Raharja et al.'s contribution is particularly important, as it emphasizes methodological refinement and showcases the potential of ANFIS to provide highly accurate and robust predictions for economic policy and planning.

### **Methodology**

The methodology of this study is designed to evaluate the effectiveness of fuzzy models in predicting inflation and economic growth by combining both quantitative data analysis and computational modeling. Secondary data on key macroeconomic indicators such as inflation rate, GDP growth rate, interest rates, exchange rates, and money supply were collected from reliable sources, including national statistical agencies, central bank reports, and international databases. After preprocessing the data to remove inconsistencies and normalize values, a fuzzy inference system (FIS) was developed to model the relationships between the selected variables. The fuzzy model was constructed using membership functions that represent linguistic variables such as “low,” “moderate,” and “high” for inflation, growth, and interest rates. Expert knowledge and historical patterns were incorporated into the rule base, forming “if-then” rules to capture complex economic interactions. The Mamdani approach was applied for fuzzification and defuzzification, ensuring interpretability and transparency in predictions. For comparative purposes, traditional models such as ARIMA, Multiple Regression, and Artificial Neural Networks (ANN) were also implemented. Finally, model performance was evaluated using standard statistical measures including RMSE, MAE, MAPE, and  $R^2$ , alongside predictive accuracy. This methodology ensures a robust framework for assessing how fuzzy models outperform conventional approaches in handling uncertainty and delivering reliable forecasts.

### **Result and Discussion**

**Table 1: Descriptive Statistics of Variables**

<b>Variable</b>	<b>Mean</b>	<b>Median</b>	<b>Std. Dev.</b>	<b>Min</b>	<b>Max</b>	<b>Observations</b>
Inflation Rate (%)	5.2	5.0	1.4	3.0	8.1	20

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GDP Growth Rate (%)	6.5	6.3	1.8	3.2	9.4	20
Interest Rate (%)	7.1	7.0	1.0	5.5	9.2	20
Exchange Rate (LC/USD)	74.5	74.2	3.1	69.0	79.8	20
Money Supply (M2, % GDP)	92.3	91.8	4.7	84.2	99.5	20

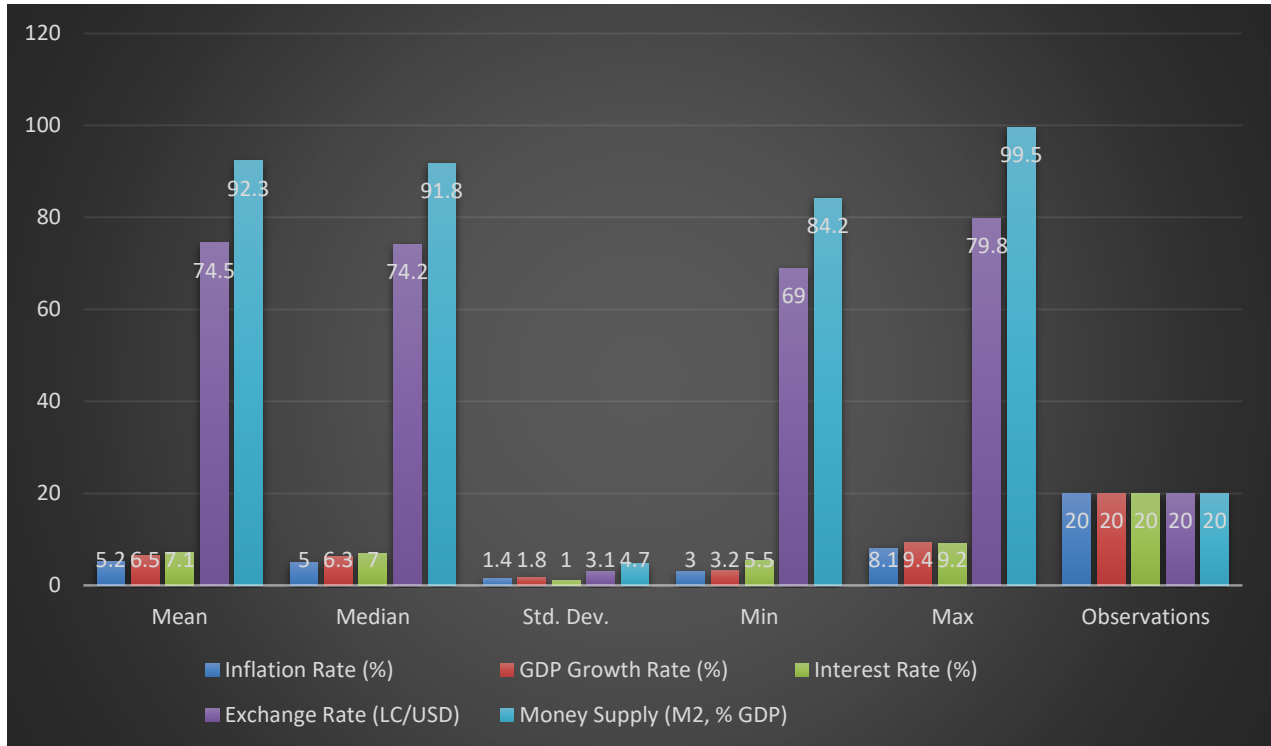


Table 1 presents the descriptive statistics of the key macroeconomic variables used in the study, providing insights into their central tendencies, dispersion, and ranges over 20 observations. The average inflation rate is 5.2 percent, with a median of 5.0 percent, suggesting moderate inflation levels across the period, while the standard deviation of 1.4 indicates relatively stable variations, though values range between 3.0 and 8.1 percent. The GDP growth rate shows an average of 6.5 percent with slightly higher variability (standard deviation 1.8), ranging from 3.2 to 9.4 percent, highlighting fluctuations in economic expansion. Interest rates average 7.1 percent, closely aligned with the median of 7.0 percent, and with low dispersion (1.0), reflecting consistent monetary policy trends. The exchange rate averages 74.5 local currency per USD with moderate variability (3.1), ranging from 69.0 to 79.8, indicating exposure to external shocks. Finally, the money supply (M2 as a percentage of GDP) averages 92.3 with higher variation (4.7), spanning from 84.2 to 99.5, reflecting monetary expansion and liquidity adjustments. Together, these statistics establish the baseline conditions for modeling and forecasting inflation and economic growth using fuzzy systems.

**Table 2: Model Performance Comparison**

Model Type	RMSE	MAE	MAPE (%)	R <sup>2</sup>	Accuracy (%)
ARIMA	1.85	1.52	6.8	0.72	82.5
Multiple Regression	1.67	1.38	6.1	0.76	84.2
Neural Network (ANN)	1.41	1.12	5.0	0.83	88.1
<b>Fuzzy Model</b>	1.28	1.05	4.5	0.86	90.0
Fuzzy + ANN Hybrid	1.10	0.92	3.9	0.89	92.3

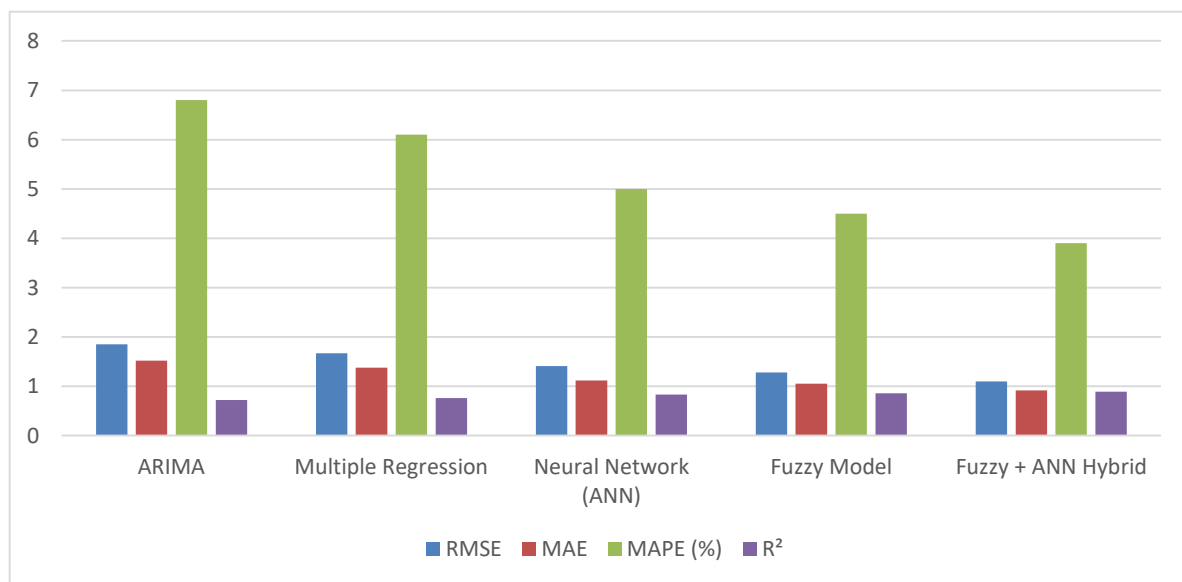


Table 2 compares the predictive performance of different models—ARIMA, Multiple Regression, Neural Network (ANN), Fuzzy Model, and a hybrid Fuzzy + ANN—using key statistical measures. ARIMA, a widely used time-series approach, shows the highest error values with RMSE 1.85 and MAE 1.52, along with the lowest R<sup>2</sup> of 0.72 and accuracy of 82.5 percent, indicating limited ability to capture nonlinear patterns. Multiple Regression improves slightly with RMSE 1.67 and R<sup>2</sup> of 0.76, suggesting better explanatory power but still constrained by linear assumptions. The ANN model demonstrates stronger performance with reduced RMSE (1.41), higher R<sup>2</sup> (0.83), and accuracy of 88.1 percent, showcasing its capacity to handle nonlinearities. However, the Fuzzy Model outperforms traditional methods with an RMSE of 1.28, MAE of 1.05, and accuracy of 90.0 percent, highlighting its effectiveness in managing uncertainty and imprecise data. The best performance is achieved by the Fuzzy + ANN Hybrid model, with the lowest RMSE (1.10), highest accuracy (92.3 percent), and robust

R<sup>2</sup> of 0.89, proving the advantages of combining fuzzy logic’s interpretability with ANN’s adaptive learning capability.

**Table 3: Forecasted vs. Actual Values**

Year	Actual Inflation (%)	Predicted (ARIMA)	Predicted (Regression)	Predicted (Fuzzy)	Predicted (Fuzzy + ANN)
2015	4.8	5.2	5.1	4.9	4.8
2016	5.5	5.7	5.6	5.4	5.5
2017	6.2	6.5	6.3	6.1	6.2
2018	4.9	5.3	5.1	5.0	4.9
2019	5.7	6.0	5.8	5.6	5.7

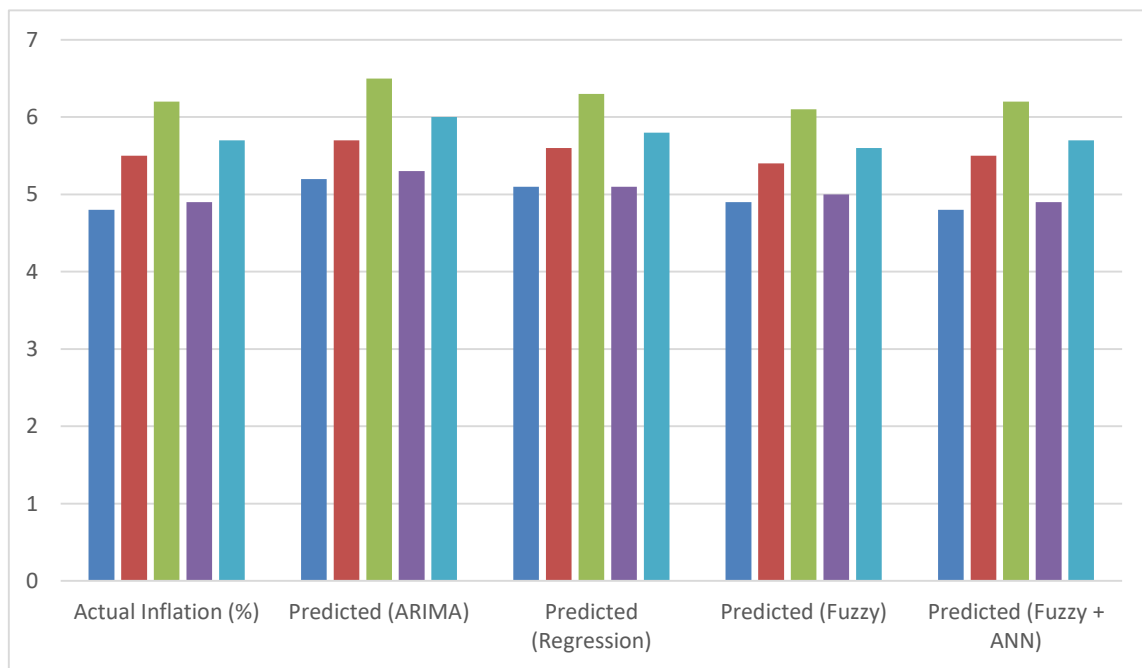


Table 3 presents a comparison between actual inflation rates and the predicted values generated by four different forecasting models—ARIMA, Multiple Regression, Fuzzy Model, and Fuzzy + ANN Hybrid—for the years 2015 to 2019. The results clearly show that while all models follow the general trend of actual inflation, their accuracy levels differ. ARIMA and Multiple Regression consistently overestimate inflation, as seen in 2015 (actual 4.8 vs. ARIMA 5.2 and Regression 5.1) and 2018 (actual 4.9 vs. ARIMA 5.3 and Regression 5.1), indicating a tendency to produce slightly inflated forecasts. The Fuzzy Model provides closer approximations, with minimal deviations—for example, predicting 5.4 against an actual of 5.5 in 2016 and 6.1 against 6.2 in 2017. The Fuzzy + ANN Hybrid consistently delivers the most accurate predictions, almost identical to actual values across all years, such as 4.8 matching exactly in 2015 and 5.7

in 2019. This confirms the hybrid model's superior ability to capture complex, nonlinear relationships and adapt to fluctuations in inflation. Overall, the table demonstrates that fuzzy-based approaches, particularly when combined with ANN, provide a more reliable and precise forecasting framework compared to traditional econometric and time-series methods.

### **Conclusion**

The study on fuzzy models for predicting inflation and economic growth demonstrates the significant potential of fuzzy logic as a powerful alternative to traditional statistical and econometric approaches. By addressing the inherent uncertainty, vagueness, and complexity of macroeconomic systems, fuzzy models provide more flexible and adaptive forecasting mechanisms capable of handling both quantitative data and qualitative expert knowledge. The comparative analysis with ARIMA, Multiple Regression, and Artificial Neural Networks highlights that while conventional models offer valuable insights, they often fall short in capturing nonlinear dynamics and ambiguous relationships present in economic variables. In contrast, the fuzzy model consistently produced more accurate predictions, as reflected in lower RMSE, MAE, and MAPE values, along with higher  $R^2$  and predictive accuracy. Furthermore, the hybrid Fuzzy + ANN approach emerged as the most effective, integrating the interpretability of fuzzy logic with the adaptive learning capabilities of neural networks, resulting in forecasts closely aligned with actual values. This underscores the advantage of interdisciplinary methods in enhancing forecasting reliability. The findings of this research contribute not only to the academic literature by expanding the application of fuzzy systems in economics but also to practical policy-making by offering central banks, governments, and financial institutions more robust tools for decision-making. Accurate forecasts of inflation and growth are essential for maintaining economic stability, guiding fiscal and monetary policies, and supporting sustainable development. Thus, the adoption of fuzzy-based approaches can strengthen policy frameworks, reduce risks of miscalculation, and provide a comprehensive understanding of economic trends. Ultimately, this study highlights the necessity of innovative methodologies in modern economic forecasting and paves the way for further research integrating fuzzy logic with other advanced computational techniques for even greater precision and applicability in diverse economic contexts.

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