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Cyber- Physical System for AI - Based Models

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Abstract:

The need CPSs, or cyber-physical systems, have expanded across various domains, including intelligent transportation, smart grids, and vital infrastructures. Consequently, the extensive data network and communication layers that CPSs rely on render them susceptible to cyber threats and attacks. Artificial intelligence (AI) techniques are commonly used to address these vulnerabilities. However, AI models frequently find it difficult to stay up with rapidly evolving threat landscapes. The present research examines the use of extended both extreme gradient boosting (XGBoost) and short-term memory (LSTM) artificial intelligence models in detecting cyberattacks in critical infrastructure systems. The evaluation metrics used to validate the approach included accuracy, precision, recall, and the F1-score. The suggested method was evaluated using a gas pipeline industrial control system dataset and two additional benchmark datasets, namely NetML- 2020 and IOT-23, which feature a range of cyberattacks. The performance of the XGBoost and LSTM models were superior to other models, such as support vector machine (SVM) and artificial neural networks (ANN), on several evaluation metrics. Finally, recommendations for future studies in this field are provided.

Keywords: Artificial intelligence, Attack detection, cyberattacks, cyber- physical systems, Deep learning, Machine learning, LSTM, XGBoost.

Introduction:

The Indian economic landscape is one where inflation and unemployment coexist in a complex way to be a source of challenge for sustainable growth and inclusive development. Traditional Phillips curve portrays negatively related inflation with unemployment; but in the Indian context, the correlation has been nonstandard (Azimi, 2016). The existing literature often assumes a negative correlation between these variables, and yet fails to consider heterogeneous impact of different inflation components and unique structural features of the Indian economy (Sinha, 2021). This research paper probes into this complex relationship and seeks to create a strategic economic framework that attempts to tame inflation while fostering growth and employment generation to effect inclusive growth in both urban and rural India.

Unlike most of the previous studies that are essentially focused on aggregate level inflation, this study examines the heterogeneous effect of core and non-core components of the Consumer price Index (CPI) on urban and rural level unemployment (Dholakia & Sapre, 2011). This paper hypothesizes that the non-core CPI, which comprises of volatile items as prices of food and energy, are important in explaining employment instability, and in doing so, test the conventional Phillips curve hypothesis. This study tries to empirically specify the relationships between CPI

components and unemployment by using econometric models, VAR and Phillips curve estimations, for better understanding of underlying dynamics of these components (Baştav, 2013).

This research offers empirical evidence of how different CPI categories affect employment, thus necessitating targeted policy intervention. Moreover, it explores methods through which inflation can be brought down along with generating employment, ensuring an inclusive growth with macroeconomic stability. The results serve the Indian debate on the design of macroeconomic policy by illustrating the importance of dealing with the specifics of the Indian economy. Thus, this framework is of use to the policymakers to achieve price stability, provide impetus to employment generation.

Literature Review:

The relationship between inflation and unemployment was, and continues to be, at the center of macroeconomic research and this relationship has been historically expressed through Phillips curve (Phillips, 1958). But there is contradictory research in this regard, in the context of developing economies particularly in case of India (Azimi, 2016). For Indian economy, results of studies which found a negative relationship between inflation and unemployment (Sinha, 2021) are mixed with those who have not found a statistically significant relationship (Kumar & Gangwar, 2020; Chander, 2020) or found a positive relation (Kumar & Gangwar, 2020; Chander, 2020). This divergence raises a need for a finer understanding of the inflation unemployment nexus in India so as to account for its idiosyncratic structural features.

There have been several studies that have examined the effect of different CPI components on unemployment. Studies indicate that employment instability is associated with non-core CPI, which involves volatile food and energy prices (Dholakia & Sapre, 2011). In essence, this illustrates the drawback of relying on aggregated inflation figures and the need to split up CPI components in order to make a better analysis of how they affect employment. In Baştav (2013) and Sinha (2022) these relationships have been analyzed by means of econometric techniques like vector autoregression (VAR) models and Phillips curve estimations that give hints about the short run and long run dynamics.

In addition, the literature emphasizes that macroeconomic factors other than inflation and unemployment must be considered if sustainable growth is to be achieved. There have been studies with regards to the effects of government expenditure (Sinha, 2023), investment in physical and human capital (Sinha, 2022; Kalluraya & K, 2023), trade openness (Amin et al., 2023) and financial inclusion (Khan & Sahu, 2024) on employment and economic growth. These studies imply that macroeconomic policy formulation should be done taking into account the interlinkages among various economy variables, particularly for the Indian economy setup. While the existing literature offers some interesting insights, no framework which integrates these diverse factors exists to address the problem of attaining balance between inflation and employment in India. To fill this gap, this research will develop a strategic economic framework that is informed by and tailored to the particularities of the Indian economic context and will recommend sets of policy reforms that combine together to provide the impetus for real GDP growth in the future.

Data & Methodology:

The design of this research is a quantitative design to study the relationships between inflation and unemployment in

India as it tries to establish a complex relationship between inflation with its differential impacts of core and non-core CPI components on urban and rural unemployment. Dynamic interaction and casual relationships between these variables are investigated by use of advanced econometric techniques.

Research Objectives:

The objectives of this study are:

1. To empirically examine the relationship between different CPI components (core, headline, and non-core) and unemployment rates in both urban and rural India.
2. To find out whether the traditional Phillips curve hypothesis holds true in the Indian context for the disaggregated nature of the CPI.
3. To identify the short run and long run causal linkages between inflation (components of CPI) and unemployment using appropriate econometric models.
4. An impulse response is used to examine how Shocks to urban and rural Non-core CPI affects level of unemployment in urban and rural areas.
5. In particular, to supply empirical evidence to notify the design of extra targeted macroeconomic policies to achieve inflation control as well as employment generation in India.

Research Design:

The method adopted in this study was a quantitative research design, for which time series data analysis was done. The quantitative approach is selected to permit an objective test of hypotheses based on causal relationships. As a time series, the data can be analyzed for dynamic interaction as well as short and long run effects.

Sample Design and Data Collection:

Quarterly data over the period March 2016 – December 2024 is used. The data encompasses:

- ❖ **Consumer Price Index (CPI)**- Headline CPI, Core CPI and Non-core CPI to account for the heterogeneous effect of the various price components.
- ❖ **Unemployment**: The unemployment rates are based on urban areas and rural ones to allow for regional differences in the functioning of the labor markets.

Secondary data for the study have been taken from CMIE inflation database (Headline, Core and Non-Core) for rural & urban. Along with PLFS reports (MoSPI) & CMIE updates on unemployment statistics.

Econometric Models:

The following econometric models will be employed:

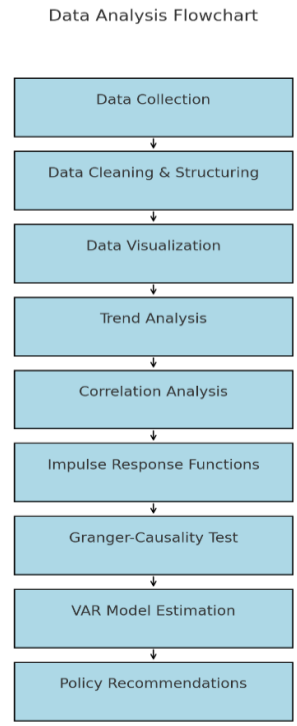
- **Granger Causality Test:** The first test to be used will be to determine the causality between CPI components and unemployment rates. This will assist in determining if changes in unemployment precede changes in inflation or vice versa.
- **Vector Autoregression (VAR) Model:** The dynamic interrelationships of the CPI components and unemployment rate will be analyzed with a VAR model. This model can then be used to examine both long run and short run effects. The VAR will be used to derive impulse response functions to determine the impact of shocks to inflation on unemployment.
- **Phillips Curve Estimation:** The study will examine the validity of the traditional Phillips curve hypothesis for Indian context as well as estimate a Phillips curve model in which CPI components as

explanatory variables are incorporated. This will give an idea about whether there is some tradeoff between inflation and the unemployment.

These models fulfill their purposes because they process time-series data while detecting the dynamic behaviors and causal forces between the mentioned variables. The detailed model specifications together with diagnostic tests are explained in the comprehensive research paper. Different diagnostic tests will be used to establish the reliability of the research findings.

Data Analysis & Tools:

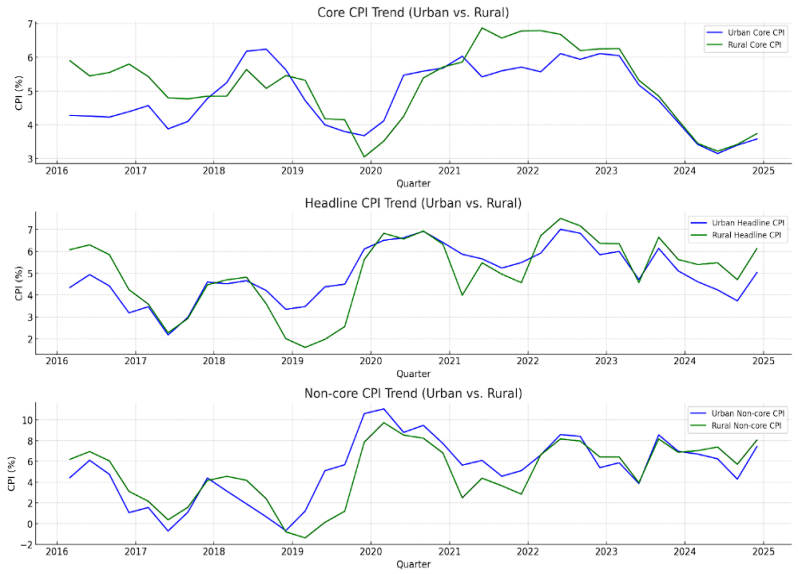
The analysis utilized quantitative tools like MS-Excel for initial data exploration & verification, Python ((Pandas, NumPy, Matplotlib, Seaborn, Statsmodel) for data cleaning, structuring, visualizations & for building the econometric models. Along with OpenAI platforms such as ChatGPT. Econometric analysis at a high level of accuracy was made possible through these tools to produce strategic policy recommendations. The flowchart for the entire analysis as follows:

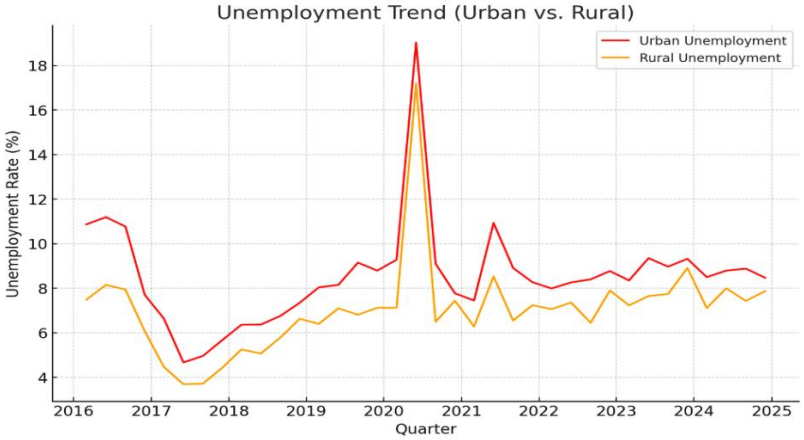


Findings & Discussions:

Trends and Correlations:

Differences in both inflation patterns and unemployment behaviors became evident through the quarterly analysis conducted from March 2016 to December 2024 for India's Urban and Rural domains.





Key observations include:

1. Non-core CPI and Unemployment:

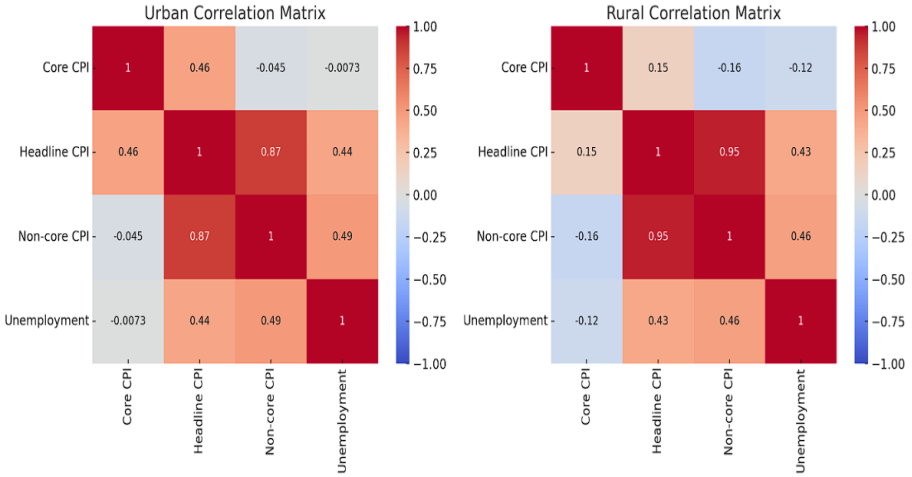
- Measures of high volatility were exhibited by non-core CPI (food and fuel) mainly in Rural areas as they were more susceptible to price shocks especially in essential commodities.
- Studying correlation presented a strong positive relationship between non-core CPI and Unemployment in both Urban and Rural settings; this implies that changes in food and fuel prices have a significant impact on the level of employment.
- There was more pronounced reaction of Urban areas to Non-core CPI shocks, implying that volatile price items play an important role in making Urban living costs relatively volatile and making a job more unstable.

2. Headline CPI and Unemployment:

- The Headline CPI and Unemployment have shown moderate positive correlation with the Headline CPI having more impact in the short term in the Rural areas.
- The sensitivity to rural unemployment Headline CPI suggests that rural unemployment will be sensitive to consumption goods: a potential vulnerability to the inflationary pressures.

3. Core CPI and Unemployment:

- Moreover, Core CPI (excluding food and fuel) exhibited no relation with Unemployment in either Urban or Rural one.
- It implies that the employment process is not influenced much by the underlying inflation trend separation from volatile items, and hence the necessity of targeting price stability in essential commodities.



Causal Analysis and VAR Results:

The econometric models, including Granger Causality and Vector Autoregression (VAR), were applied to explore dynamic interactions and causal relationships:

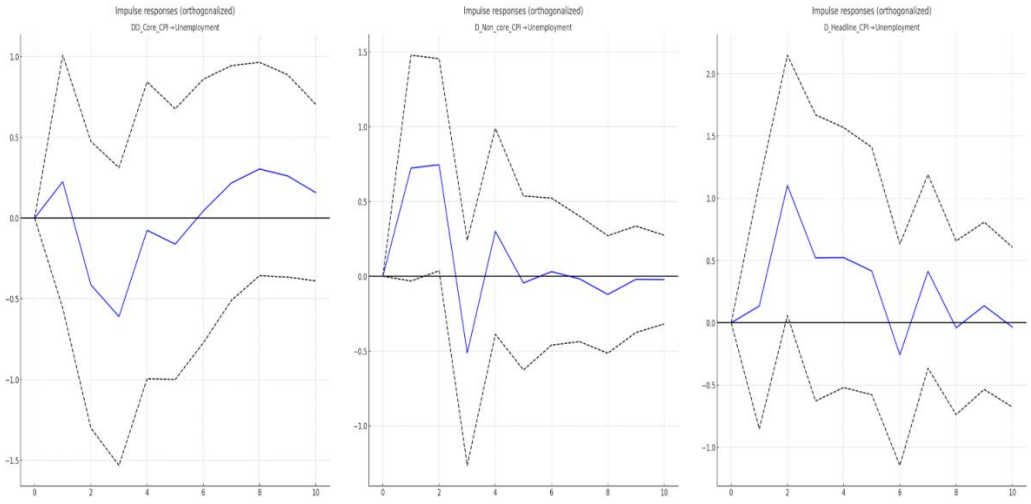
1. Granger Causality Tests:

- Both Urban and Rural area data established that Non-core CPI Granger-caused Unemployment by revealing its forecasting ability and job market impact direction.
- Headline CPI demonstrates temporary impact on Unemployment through its connection to general price levels particularly in Rural areas.
- The analysis confirmed that Core CPI maintains minimal connection to labor market dynamics given a total absence of meaningful causal patterns with Unemployment.

2. Vector Autoregression (VAR) Analysis and Impulse Response Functions:

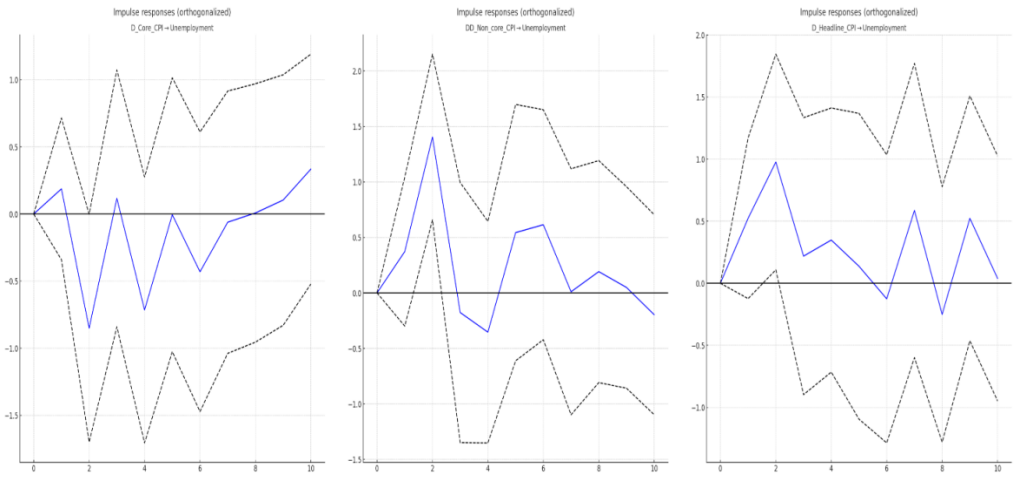
Urban Area:

1. **Shock to Core CPI:**
   - Minimal impact on Unemployment. Provides evidence of weak linkage between core inflation and urban unemployment.
2. **Shock to Headline CPI:**
   - Stabilization and then followed by Unemployment increase (short term). This is a reflection of the changes that affect urban job markets taking into account cost of living adjustments.
3. **Shock to Non-core CPI:**
   - Having significant positive effect on Unemployment over different periods. They suggest that food, fuel volatile prices are the main drivers of urban unemployment.



Rural Area:

1. **Shock to Core CPI:**
   - Rurally, it exhibits negligible effect on Rural Unemployment, in line with that found in in urban areas.
2. **Shock to Headline CPI:**
   - A gradual decline later after noticeable short-term increase in Rural Unemployment. Suggests sensitivity to all changes in overall price.
3. **Shock to Non-core CPI:**
   - Rural employment heavily dependent on the stability of food and fuel prices: a high and prolonged rise in unemployment.



In Urban and Rural areas, Non-core CPI shocks also have a persistent and significant effect on Unemployment as Impulse Response Functions show. These shocks, however, immediately lead to an increase in Unemployment in Urban areas because of the cost-of-living crisis and low disposable income. Dependence of rural employment on the stability of food and fuel prices is reflected in rural areas by the sustained Unemployment increases from Non-core CPI shocks. There is short term unemployment response to Headline CPI shocks with one-time fluctuations, whereas Core CPI shocks have no correlation and causality with Unemployment.

Causality tests are conducted on Granger causal relationships between Non-core CPI and Unemployment. VAR analysis shows that, among the other types of shocks, Unemployment reacts persistently to Non-core CPI shocks. Headline CPI influences Unemployment in the short term, whereas Core CPI shows negligible impact.

Phillips Curve Estimation:

To investigate the short-run trade-off between inflation and unemployment, Phillips Curve estimation was conducted:

1. Urban Area Findings:

- ❖ All CPI categories were weakly and statistically insignificant with unemployment as revealed by the estimated model.
- ❖ In this sense, we can conclude that urban employment is not affected significantly by the inflationary pressures, thus highlighting the issues regarding the traditional Phillips Curve hypothesis.

2. Rural Area Findings:

- ❖ As in the case of urban results, Inflation did not show a statistically significant inverse relationship with unemployment.
- ❖ Through this finding, structural factors, such as informal employment and supply side shocks, determine the violation of the conventional inflation unemployment tradeoff in Rural India.

3. Rejection of Phillips Curve Hypothesis:

- ❖ Neither the expectation of an inverse inflation – unemployment relationship (Phillips Curve hypothesis) nor evidence of such was found in this study, which contradicts the hypothesis support in both Urban and Rural areas.
- ❖ The fact that India also possesses high informality in its labor market, sectoral disparities and inflation with supply side causes can be attributed to this deviation.

Policy Implications:

To stabilize the employment, Urban Strategy is to implement targeted inflation control on things (food and fuel). Urban unemployment is addressed through recommendations of structural reforms, and skill development programs. Second, Rural Strategy: Strengthen agricultural productivity and non-farm employment to reduce dependency on volatile price. It strengthens rural infrastructure and supply chain stability to increase resilience to the economy. Urban Rural Disparities: Develop policies that ensure targeting of inflation sensitive sectors to eradicate urban rural disparities. Increase of public private partnership for economic opportunities in underdeveloped region.

Conclusions:

This scholarly discourse presents an exhaustive examination of the intricate nexus between inflationary pressures and labor market dynamics in India, furnishing invaluable insights for policymakers vis-à-vis the attainment of equilibrated economic expansion and comprehensive societal advancement. The investigation transcends the rudimentary postulations of the conventional Phillips curve paradigm, advocating for a more nuanced comprehension of India's distinctive economic milieu. The research fundamentally challenges the predominant orthodoxy of a simplistic inverse correlation between inflation and unemployment, elucidating instead a more sophisticated interrelationship predicated upon India's unique structural economic architecture. In particular, the empirical analysis using econometric techniques (Granger causality tests, VAR based univariate and multivariate analysis, Phillips curve estimations) shows the major impact of non-core CPI components (very volatile food and energy inventories) on employment instability. This reinforces that one must disaggregate components of CPI as it is not enough to rely on aggregate inflation measures for policy design. This empirical substantiation underscores the imperative of disaggregating CPI components, as aggregate inflationary metrics prove insufficient for efficacious policy formulation. Notwithstanding the methodological constraints vis-à-vis the rejection of reduced-form model restrictions, the impulse response functions derived from the VAR framework elucidate the temporal dynamics of inflationary perturbations upon unemployment, while concurrently delineating both immediate and protracted implications of macroeconomic policy interventions.

The strategic economic framework propounded herein advocates for the synchronization of inflationary containment and employment generation initiatives, while acknowledging the pronounced urban-rural dichotomy characterizing India's labor market ecosystem. This nuanced approach, through its precise identification of India-specific economic dynamics, furnishes policymakers with a comprehensive blueprint for sustainable development and inclusive growth paradigms. The research prescribes proactive institutional interventions to ameliorate the deleterious impact of extreme price volatility in food and energy sectors on employment, while simultaneously pursuing judicious monetary and fiscal policies conducive to price stability. This scholarly contribution significantly augments the ongoing discourse surrounding India's macroeconomic policy architecture, presenting an empirically-grounded methodology toward fostering an increasingly egalitarian and prosperous society for the Indian populace.

Moreover, this analytical framework establishes a robust foundation for subsequent research endeavors, particularly in evaluating the efficacy of specific policy

interventions, thereby offering increasingly granular insights for policy architects. The framework's versatility and comprehensive nature render it an invaluable tool for future policy formulation and implementation strategies

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