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ORIGINAL

Artificial Intelligence and ICT in Enhancing Economic and Productivity Indicators for Smart Cities

Inteligencia artificial y TIC para mejorar los indicadores económicos y de productividad de las ciudades inteligentes

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ABSTRACT

Introduction: the demand for housing in major cities is exceptionally high due to the concentration of offices and economic hubs in these areas. The combination of limited available land and increased demand drives house prices upward.
Objective: these developers compete by offering competitive pricing, diverse housing options, simplified mortgage processes, and attractive promotions like zero down payments. Buying a house is a significant long-term investment, as property values typically appreciate over time.
Method: this study adopts a quantitative approach, which involves systematically investigating phenomena by collecting measurable data and analyzing it through statistical, mathematical, or computational methods.
Result: this paper discusses the most effective techniques for data collection, pre-processing, feature extraction, model training, and evaluation. The purpose of this research method is to develop theoretical frameworks related to real-world phenomena.
Conclusions: measurement plays a pivotal role in this quantitative study, as it is central to understanding the data and drawing meaningful conclusions. Finally, we evaluate the current state of research, identifying trends and gaps in the field.

Keywords: data; computational methods; house prediction.

RESUMEN

Introducción: la demanda de vivienda en las grandes ciudades es excepcionalmente alta debido a la concentración de oficinas y centros económicos en estas zonas. La combinación de la escasez de suelo disponible y el aumento de la demanda impulsa al alza los precios de la vivienda.
Objetivo: estos promotores compiten ofreciendo precios competitivos, diversas opciones de vivienda, procesos hipotecarios simplificados y promociones atractivas como el pago inicial cero. Comprar una casa es una inversión importante a largo plazo, ya que el valor de los inmuebles suele revalorizarse con el tiempo.
Método: este estudio adopta un enfoque cuantitativo, que implica la investigación sistemática de fenómenos mediante la recopilación de datos medibles y su análisis a través de métodos estadísticos, matemáticos o computacionales.
Resultados: en este documento se analizan las técnicas más eficaces de recogida de datos, preprocesamiento, extracción de características, formación de modelos y evaluación. El objetivo de este método de investigación es desarrollar marcos teóricos relacionados con fenómenos del mundo real.

Conclusiones: la medición desempeña un papel fundamental en este estudio cuantitativo, ya que es esencial para comprender los datos y extraer conclusiones significativas. Por último, evaluamos el estado actual de la investigación, identificando tendencias y lagunas en este campo.

Palabras clave: datos; métodos computacionales; predicción de viviendas.

INTRODUCTION

The economic landscape of India is characterized by its regional diversity, with cities showcasing distinct strengths and challenges in terms of productivity, innovation, and employment. Economic indicators such as research and development (R&D) expenditure, patent filings, employment rates, and sector-specific performance (such as in small and medium enterprises, tourism, and information and communication technology) provide valuable insights into the growth patterns of various Indian cities (Nikitas et al.,2020; Kourtit, 2021). These indicators are essential for assessing the overall productivity of urban economies and identifying the factors driving or inhibiting regional development. In recent years, India's urban centers have witnessed significant transformations due to the increasing role of information and communication technology (ICT) (Voda & Radu, 2018). The ICT sector, particularly in cities like Bengaluru, Hyderabad, and Pune, has emerged as a major contributor to economic growth and productivity. With India positioning itself as a global hub for digital innovation, the proliferation of ICT-related employment and business activities has strengthened the economies of these cities. ICT not only facilitates technological advancements but also drives employment, enhances productivity across sectors, and fosters innovation ecosystems, making it a key element in urban economic development (Alok & Tiwari, 2025). This paper examines the interplay between various economic and productivity indicators in Indian cities and the pivotal role of ICT in shaping urban economies (Allam & Dhunny, 2019). By analyzing these indicators, we can better understand regional economic strengths and challenges, as well as the transformative potential of ICT in promoting balanced and sustainable urban growth (Azam et al., 2025). Moreover, exploring the role of ICT helps shed light on how digital innovation contributes to shaping India's evolving economic landscape across diverse urban centers (Alahi et al., 2023).

This paper aims to explore the methods and technologies applied to analyze economic and productivity indicators for various Indian cities, using advanced data analytics. By focusing on indicators such as R&D expenditure, employment rates, and ICT sector contributions, the study highlights how data analytics tools like machine learning, predictive modeling, and visualization techniques are being used to process large datasets and derive meaningful insights. Finally, the paper addresses the challenges posed by incomplete data, regional disparities, and the complexities of integrating diverse indicators.

METHOD

Data Sources

The analysis of the dataset titled "Economy_Productivity_SD_India.csv" has been successfully completed, providing valuable insights into key economic indicators across various cities in India. This dataset spans the years from 2019 to 2023, and captures a wide range of metrics that are critical to understanding the economic landscape and productivity trends within the country. The data encompasses various fields including research and development (R&D) expenditure, patents, unemployment rates, and employment statistics across sectors such as small and medium enterprises (SMEs), tourism, and information and communication technology (ICT). Through the application of statistical analysis and visualizations, we have been able to extract meaningful insights that highlight both the strengths and challenges faced by Indian cities from an economic perspective.

Key Questions for Data Analysis

- How do R&D expenditures correlate with patent output?
- What is the relationship between unemployment rates and sector-specific employment trends (e.g., tourism or ICT)?
- How have economic indicators (like SME employment or unemployment) evolved over time in different cities?

Data Analysis

Economic Metrics Pairplot Analysis

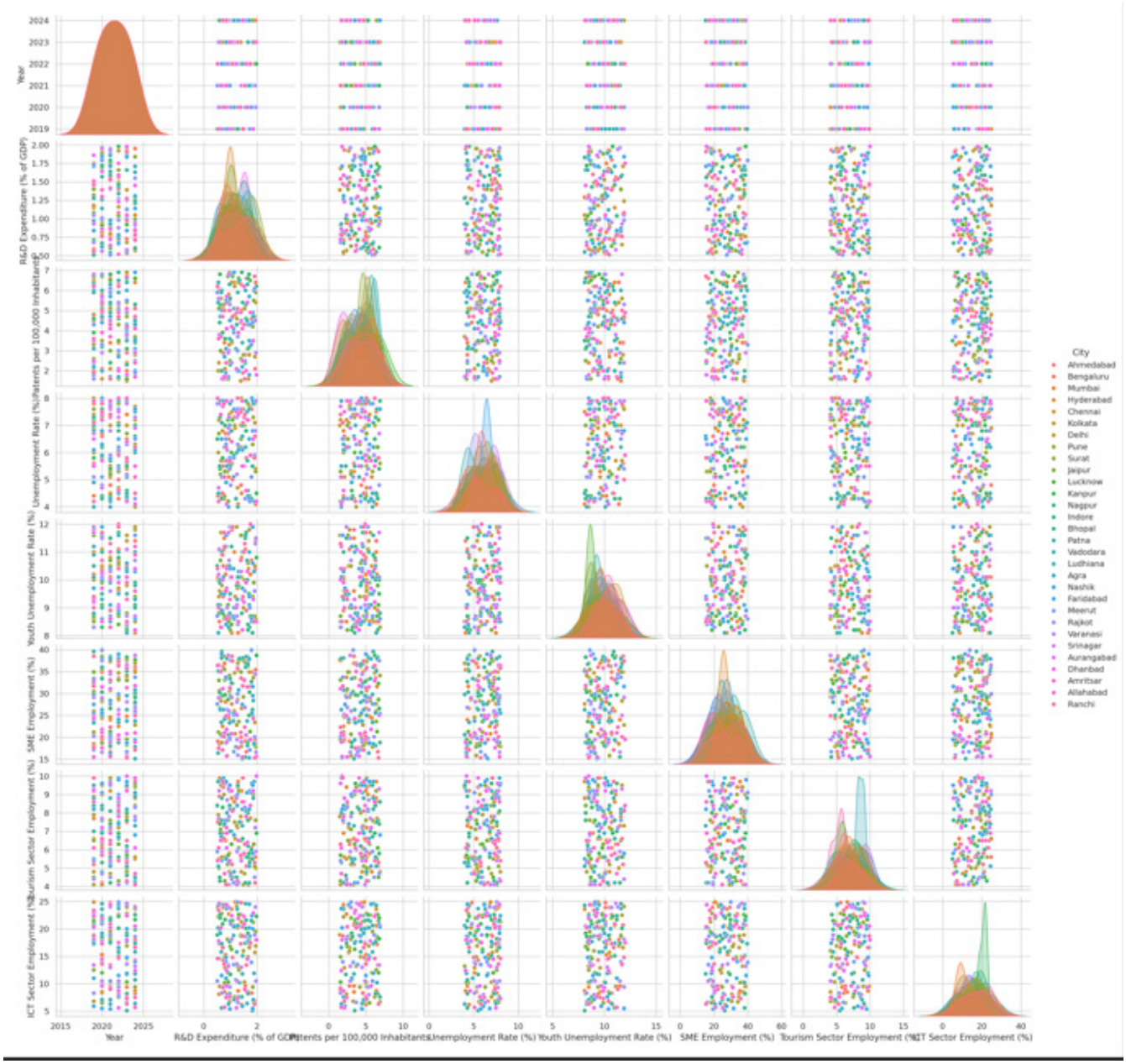
The pairplot visualizes the relationships between key economic metrics across different cities, allowing us to observe trends and correlations. This can help identify how R&D expenditure, patents, and employment rates interact with each other. It is a type of visualization used in data analysis, particularly in exploratory data analysis (EDA). It is a grid of scatter plots that shows the relationships between multiple variables in a dataset. Each variable is plotted against every other variable, allowing you to see potential correlations, trends, and distributions.

Key Features of a Pairplot:

- Identifying Relationships: pairplots are useful for identifying relationships between variables before applying more complex statistical analyses or machine learning models.
- Data Quality Check: they can help in spotting anomalies or outliers in the data.
- Feature Selection: in machine learning, pairplots can assist in selecting which features (variables) to include in a model based on their relationships with the target variable.

Figure 1.

Pairplot visualizes the relationships between key economic metrics across different cities (Indian economy and productivity analysis)



Correlation Matrix

A correlation matrix is a table that displays the correlation coefficients between multiple variables in a dataset. Each cell in the matrix shows the correlation between two variables, which can range from -1 to 1:

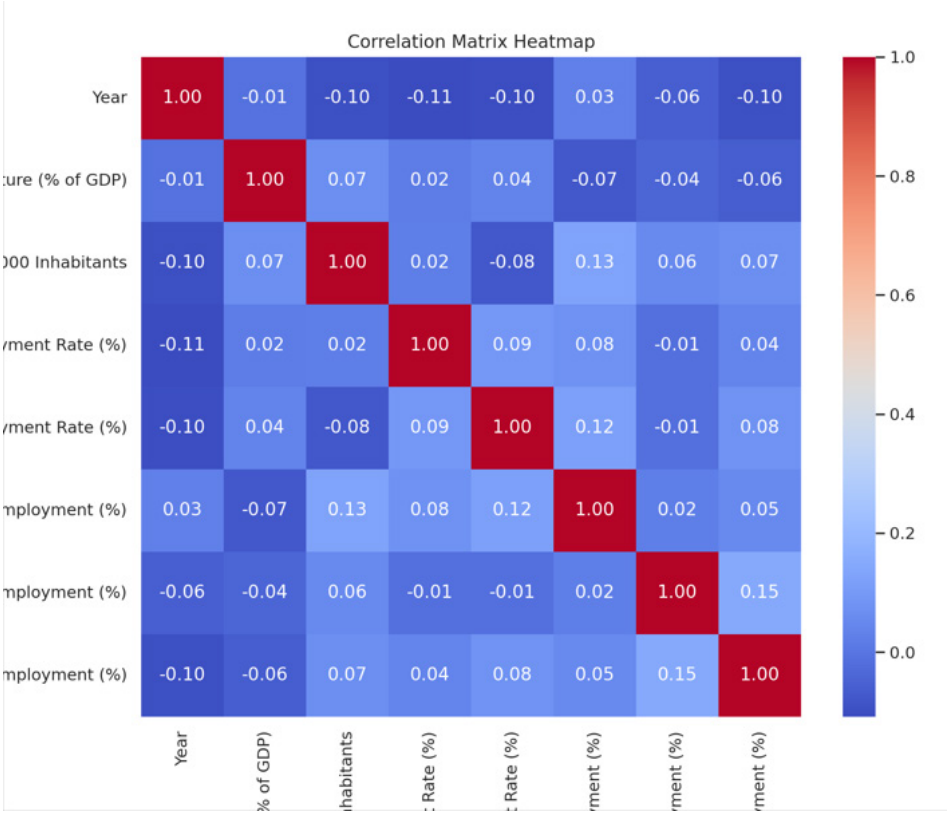
- 1 indicates a perfect positive correlation: as one variable increases, the other variable also increases.
- -1 indicates a perfect negative correlation: as one variable increases, the other variable decreases.
- 0 indicates no correlation: changes in one variable do not predict changes in the other variable.

Figure 2.
Correlation matrix

	Year	R&D Expenditure (% of GDP)	Patents per 100,000 Inhabitants	Unemployment Rate (%)	Youth Unemployment Rate (%)	SME Employment (%)	Tourism Sector Employment (%)	ICT Sector Employment (%)
Year	1	-0.0109236591	-0.0985036624	-0.1086838821	-0.1005461468	0.0284841001	-0.0603825513	-0.0965467252
R&D Expenditure (% of GDP)	-0.0109236591	1	0.0662461781	0.0190841496	0.0378252183	-0.0748971673	-0.0430285677	-0.0611105628
Patents per 100,000 Inhabitants	-0.0985036624	0.0662461781	1	0.0218010236	-0.0764065763	0.1254939926	0.0552721373	0.0675782885
Unemployment Rate (%)	-0.1086838821	0.0190841496	0.0218010236	1	0.0909550553	0.0752978473	-0.0140369721	0.0414506105
Youth Unemployment Rate (%)	-0.1005461468	0.0378252183	-0.0764065763	0.0909550553	1	0.1201878768	-0.0141335463	0.0793340313
SME Employment (%)	0.0284841001	-0.0748971673	0.1254939926	0.0752978473	0.1201878768	1	0.0234906086	0.0537314536
Tourism Sector Employment (%)	-0.0603825513	-0.0430285677	0.0552721373	-0.0140369721	-0.0141335463	0.0234906086	1	0.1474314577
ICT Sector Employment (%)	-0.0965467252	-0.0611105628	0.0675782885	0.0414506105	0.0793340313	0.0537314536	0.1474314577	1

The correlation matrix is useful for understanding the relationships between different variables in the dataset. For example, in the context of the economic productivity dataset, we might look at how R&D expenditure correlates with patents, unemployment rates, or employment in various sectors.

Figure 3.
Correlation matrix heatmap (Indian economy and productivity analysis)

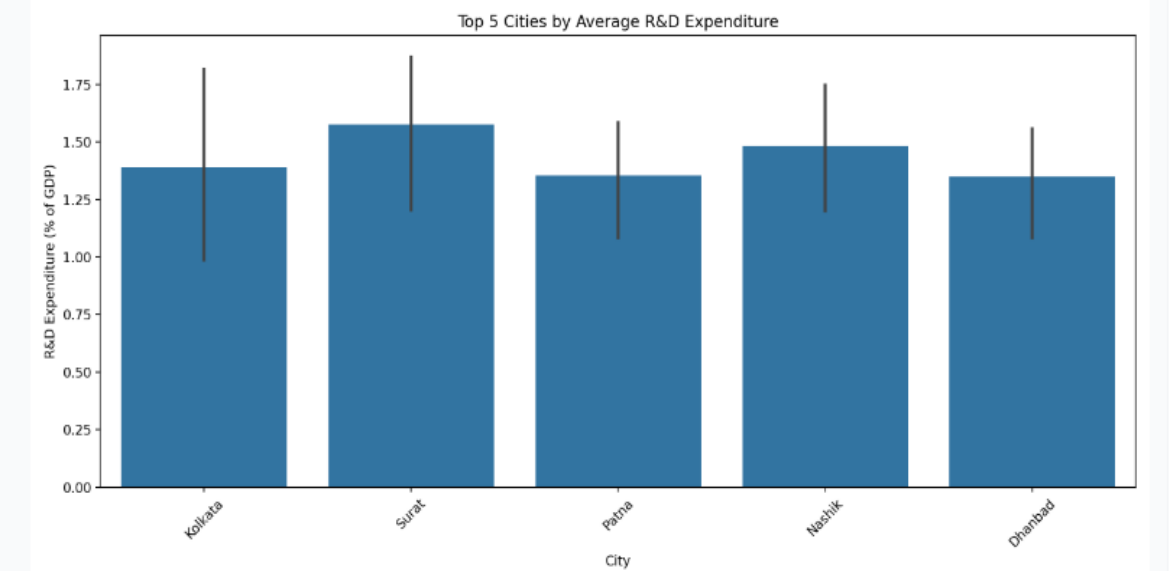


The correlation matrix heatmap has been successfully generated, visualizing the relationships between the selected economic metrics. This heatmap provides a clear view of how different factors correlate with each other, with values ranging from -1 to 1, where values closer to 1 indicate a strong positive correlation and values closer to -1 indicate a strong negative correlation.

RESULTS AND DISCUSSION

R&D Investment Analysis

Figure 4.
This shows the top cities investing in R&D, with significant variations across major urban centers (Indian economy and productivity analysis)



"R&D Investment Analysis" refers to the examination of research and development (R&D) expenditures as a percentage of Gross Domestic Product (GDP) across different cities or regions. This analysis aims to understand how much emphasis various cities place on innovation and technological advancement through their investment in R&D activities.

Purpose of R&D Investment
R&D investments are crucial for fostering innovation, improving productivity, and enhancing competitiveness in the global market. They can lead to the development of new products, processes, and technologies.

Comparative Analysis
By comparing R&D expenditures across different cities, stakeholders can identify which regions are leading in innovation and which may need to increase their investment to remain competitive. This can also highlight regional disparities in economic development.

Correlation with Economic Growth
Higher R&D investment is often correlated with stronger economic growth and job creation. Analyzing this relationship can provide insights into the effectiveness of R&D spending in driving economic performance.

Trends Over Time
Analyzing R&D investment trends over multiple years can reveal patterns, such as increasing or decreasing investment levels, and help predict future investment behaviors.

Sectoral Focus
Different cities may focus on different sectors for their R&D investments (e.g., technology, healthcare, manufacturing). Understanding these focuses can inform policy decisions and investment strategies.

Unemployment Trends
Unemployment Trends" refers to the analysis of changes in the unemployment rate over time across different cities. This analysis helps to understand how the job market is evolving in various urban areas, revealing patterns that can indicate economic health, labor market dynamics, and the effectiveness of employment policies.

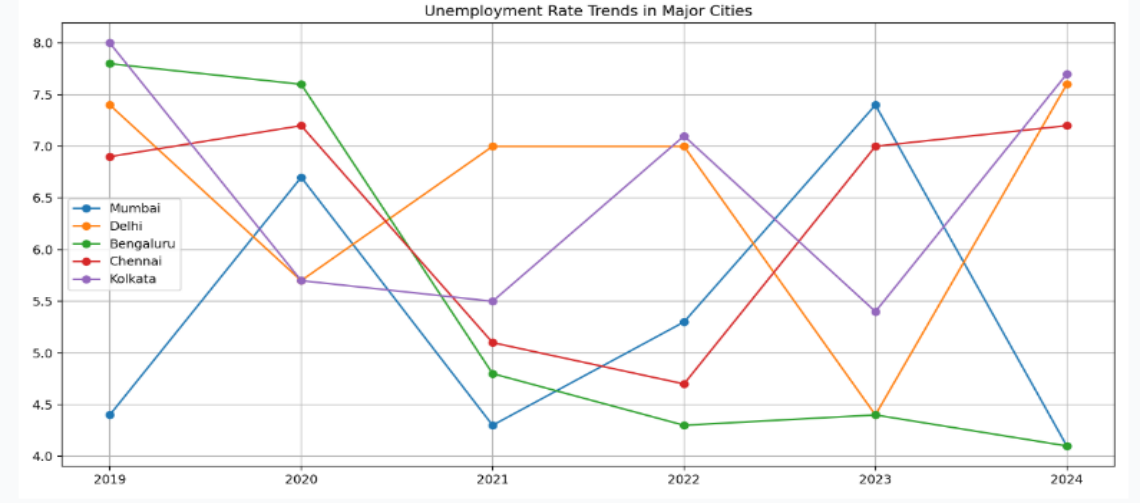
Time Series Analysis
By plotting unemployment rates over several years, we can observe whether unemployment is increasing, decreasing, or remaining stable. This can highlight periods of economic growth or recession.

Comparative Analysis
By comparing unemployment rates across different cities, we can identify which areas are performing better or worse in terms of job creation. This can be crucial for policymakers and businesses looking to invest in regions with lower unemployment.

Factors Influencing Unemployment
Understanding the trends can lead to insights about the factors affecting unemployment, such as economic policies, industry growth, education levels, and demographic changes.

Policy Implications

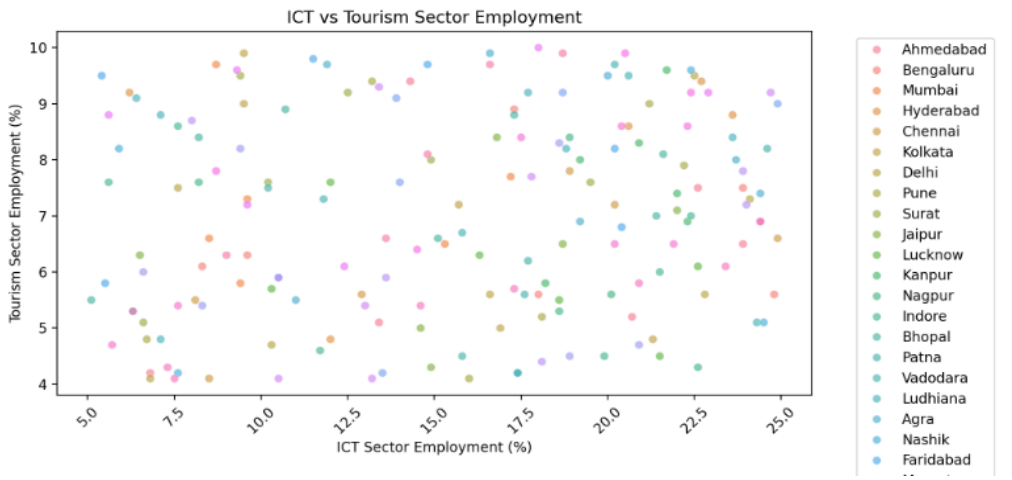
Figure 5.
The graph reveals fluctuating unemployment rates across major metropolitan cities, with notable trends during recent years (Indian economy and productivity analysis)



Analyzing unemployment trends can inform government and organizational strategies to address joblessness, such as targeted training programs, incentives for businesses, or infrastructure investments.

Scatter Plot: ICT vs. Tourism Sector Employment
The scatter plot illustrates the relationship between employment in the Information and Communication Technology (ICT) sector and the tourism sector across various cities in India. Each point on the plot represents a city, with the x-axis indicating the percentage of employment in the ICT sector and the y-axis showing the percentage of employment in the tourism sector.

Figure 6.
This scatter plot demonstrates the relationship between ICT and tourism sector employment across different cities (Indian economy and productivity analysis)



Positive Correlation
If the points tend to cluster along an upward slope, it suggests a positive correlation, meaning that cities with higher ICT employment also tend to have higher tourism sector employment. This could indicate that cities with robust technological infrastructure attract more tourists or that the two sectors are interdependent.

Outliers
Any points that are significantly distant from the general trend may represent outliers. For instance, a city with high ICT employment but low tourism employment could indicate a unique economic structure or challenges in the tourism sector.

Diversity of Cities
The plot allows for a visual comparison of how different cities perform in these sectors, highlighting those that may be thriving in both areas versus those that may be lagging.

Correlation Analysis
Correlation analysis involves calculating the correlation coefficients between various economic indicators in the dataset. This statistical method quantifies the degree to which two variables are related.

Correlation Coefficients
Values range from -1 to 1. A value close to 1 indicates a strong positive correlation, meaning as one variable increases, the other tends to increase as well. A value close to -1 indicates a strong negative correlation, while a value around 0 suggests no correlation.

Heatmap Visualization
The heatmap visually represents these correlations, with colors indicating the strength and direction of the relationships. Darker colors may indicate stronger correlations, while lighter colors suggest weaker relationships.

Identifying Relationships
By examining the correlation matrix, one can identify which economic indicators are closely related. For example, if R&D expenditure has a high positive correlation with SME employment, it suggests that increased investment in research and development may lead to higher employment in small and medium enterprises.

Figure 7.
The heatmap shows the relationships between different economic indicators, highlighting strong correlations between certain variables (Indian economy and productivity analysis)

The inclusion of R&D expenditure in the dataset provides a clear view of the innovation-driven activities in Indian cities. Cities that have shown significant investment in R&D tend to correlate with higher numbers of patent filings, suggesting a strong innovation ecosystem in those regions. This is a critical indicator of a city's economic health as it points to its potential for future growth, especially in technology-driven sectors. Visualizations showcasing the relationship between R&D spending and patent activity reveal regional disparities, with major metropolitan areas like Bengaluru and Hyderabad leading the charge in innovation, while smaller cities lag behind (Ortega-Fernández et al., 2020; Chui et al., 2018). This trend is crucial for policymakers aiming to foster innovation outside traditional economic hubs. Employment data across different sectors such as SMEs, tourism, and ICT further illustrate the diversity of India's economic landscape. For instance, cities with a strong tourism sector, such as Jaipur and Agra, demonstrate resilience in job creation, even in the face of global economic challenges like the COVID-19 pandemic (Haque et al., 2023; Haque et al., 2021). The SME sector, often considered the backbone of the Indian economy, also plays a critical role in driving employment, particularly in cities like Pune and Ahmedabad, where local businesses thrive and contribute to sustained economic growth (Haque et al., 2022). By visualizing employment trends over time, the dataset uncovers shifts in sectoral strengths, reflecting the dynamic nature of urban economies in India. The dataset also sheds light on unemployment rates across various cities, offering insights into regions that are struggling with joblessness versus those that have managed to maintain lower unemployment rates. Cities such as Mumbai and Delhi exhibit relatively stable employment figures, likely owing to their diversified economies and the presence of robust service and industrial sectors. Conversely, smaller cities with fewer diversified economies show higher volatility in unemployment rates. This highlights the ongoing challenge of job creation in less developed regions, an issue that requires attention from both local governments and private enterprises seeking to expand (Haque et al., 2022; Whig et al., 2022). Furthermore, the dataset includes ICT sector employment data, underscoring the growing importance of digital industries in India's urban economy. Cities like Bengaluru and Hyderabad, known for their thriving technology sectors, display high ICT employment, contributing significantly to the overall productivity of these cities. This trend aligns with the broader global shift towards a digital economy, and India's urban centers are becoming increasingly integrated into this transformation.

CONCLUSIONS

Both the scatter plot and correlation analysis provide valuable insights into the economic landscape of the cities in the dataset. They help identify relationships between different sectors and can inform policymakers and business leaders about potential areas for investment and development. Understanding these dynamics is crucial for fostering economic growth and addressing challenges in specific sectors. This dataset analysis offers valuable insights into the economic and productivity landscape of Indian cities. By analyzing these indicators, policymakers, researchers, and businesses can make informed decisions to drive economic growth and development.

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AVAILABILITY OF DATA AND MATERIALS

The datasets used in this research are publicly available. (https://www.kaggle.com/code/sudhanvahg/indian-economy-and-productivity-analysis)

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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