Advanced Mathematical Statistics MTH - 522 Project 3

Integrated Analysis of Economic Indicators for Inclusive Growth in the City of Boston

Authors

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1. **The Issues:**

This inquiry digs into crucial economic concerns affecting Boston, revealing trends and patterns that define the city's future. We investigate the complexity impacting growth and resilience in the heart of Massachusetts, from Logan Airport dynamics to real estate difficulties.

- What is the overall trend in Logan Airport passenger statistics, considering both domestic and international passengers?
- What factors contribute to the seasonal fluctuations in the hotel occupancy rate and average daily rate for Boston?
- What challenges does the declining trend in total jobs pose for Boston, and what factors contribute to this trend?
- How is the unemployment rate expected to change in 2020, and what are the underlying factors influencing its fluctuations?
- What are the main drivers of the increasing trend in labor force participation for Boston, and how do unexpected fluctuations impact this trend?
- How can the increasing demand for real estate units be managed effectively, considering the regular seasonal patterns and fluctuations?
- What factors contribute to the declining trend in the total development cost of approved projects, and how can pipeline firms make informed budgeting decisions?
- What insights can be gained from the increasing trend in the square feet of approved projects, and how does seasonal demand impact this trend?
- How do seasonal patterns and rising energy demand contribute to the gradual expansion of construction jobs in pipeline construction?
- What are the key factors influencing the declining foreclosure rates, and how can this trend impact government interventions and financial decisions?
- What economic factors contribute to the decline in foreclosure deeds, and how does this impact the overall stability of the housing market?
- What are the driving forces behind the progressive decline in the median housing sales price, and how are economic conditions and external causes influencing these changes?
- What factors explain the general increase in the number of houses sold over time, and how does the seasonal pattern impact sales dynamics?
- What trends and seasonal patterns are observed in new housing construction permits, and how can businesses and policymakers leverage this data for planning?
- What economic and housing market conditions contribute to the recent drop in new affordable housing permits in Boston, and how can policymakers respond to this decline?

2. Findings:

- **Number of domestic and international passengers at Logan Airport**
  The review of Logan Airport passenger statistics revealed a constant rising trend, with peak summer travel and decreased winter visitation. The study correctly described most of the data changes, with just minor irregularities.

- **Total international flights at Logan Airport**
  Logan International Airport has had a constant increase in flights, which is most likely due to increased interest in air travel. Flights are at their highest during the summer and at their lowest during the winter. Flight numbers may still vary owing to reasons such as weather or special events. Overall, the trend shows that departures from the airport will continue to climb.

- **Hotel occupancy for Boston**
  The hotel occupancy rate is increasing, following a stable seasonal trend with summer peaks and winter lows. Increased tourism and online booking may have an impact on this good trend. Managers can utilize this information to develop promotions during slow periods and to target specific client segments for increased profitability.

- **Hotel average daily rate for Boston**
  Hotel prices have risen in general, with significant seasonal differences - greater in the summer, cheaper in the winter. Price increases have recently decreased, presumably due to increased competition and economic developments. The seasonal trend has become more pronounced, most likely because individuals prefer to travel during the summer. Random price variations, caused by global economic uncertainty and extraordinary occurrences, have also grown less predictable. Prices are rising overall, but trends and fluctuations are changing.

- **Total Jobs**
  The graph depicts a concerning trend of job loss in Boston. Despite cyclical swings, there is a substantial drop, which is most likely affected by automation, globalization, and the loss of manufacturing jobs. The COVID-19 pandemic in 2020 will exacerbate this tendency. To address this issue and boost job growth, policymakers should consider investing in education, promoting domestic job creation, and infrastructural initiatives.

- **Unemployment rate for Boston**
  The unemployment rate in Boston has typically declined, but it is expected to rise in 2020 because of the pandemic. There are some seasonal fluctuations, with summer

seeing higher unemployment. Unpredictable events, such as economic shocks, contribute to volatility. It's a confluence of long-term tendencies, seasonal patterns, and unforeseen factors.

- Labor rate for Boston
  Labor-force participation has been steadily increasing over time, with periodic swings due to factors such as school schedules and weather. Unexpected fluctuations are seen, presumably because of economic developments. While the analysis captures broad changes accurately, it assumes regular seasonal patterns. Finally, the analysis gives useful insights for forecasting future trends and measuring the impact of various factors on workforce dynamics.

- Number of units approved
  The graph depicts an increasing trend in real estate unit demand, with regular seasonal ups and downs, with winter being the highest season. The research implies that future demand will rise more, underscoring the significance of taking seasonal fluctuations into account when planning maintenance and operations. Overall, the data is forecastable, capturing clear trends with few unexplained swings.

- Total development cost of approved projects
  Overall, pipeline development expenses have been declining, with a regular seasonal pattern—higher in the winter and lower in the summer. The small random variations indicate that the model is a good fit for cost analysis. This knowledge enables pipeline firms to make smart budgeting decisions, anticipate seasonal swings, and accurately forecast future expenses.

- Square feet of approved projects
  The need for pipeline square feet is increasing, with a significant increase trend. Seasonal patterns show that demand is higher in the spring and summer, and lower in the fall and winter. This data can assist firms in better understanding and responding to client needs.

- Construction jobs
  Jobs in pipeline construction have been gradually expanding, owing to rising energy demand and investments in renewables. With a tiny inexplicable variance, the graph reveals a consistent pattern of peaks and dips connected to seasons. This indicates a high demand for workers, and firms and job seekers should be aware of these patterns to make better planning decisions.

- Foreclosure house petitions

Overall, foreclosure rates are declining, with higher rates in the winter and spring and lower rates in the summer and fall. There are still random changes, and the seasonal pattern is more obvious in early eras. Recent years have revealed an accelerated deterioration. This data is useful for governments, businesses, and individuals planning interventions, forecasting service demand, and making sound financial decisions.

- Foreclosure house deeds
  Because of a solid economy, cheaper mortgage rates, and government aid programs, foreclosure deeds have been on the fall. The most recent figures reveal a dramatic drop, hitting its lowest point since 2006. This positive trend indicates improved mortgage affordability, which allows individuals to stay in their houses longer and contributes to a stable housing market.

- Median housing sales price
  The median price of a home has been progressively declining, with a clear seasonal pattern of higher prices in the summer and lower prices in the winter. Price changes may also be impacted by economic conditions or other external causes.

- Number of houses sold
  According to the data, home sales have generally increased over time, probably due to variables such as population growth and economic conditions. There is a seasonal pattern, with increased sales in the spring and summer. The remaining changes point to a variety of effects, such as regional differences and individual situations. Overall, this analysis aids us in comprehending the shifting dynamics of the housing market.

- New housing construction permits
  According to the data, there has been a constant growth in new dwelling building, with a clear tendency of increasing activity in the spring and summer. This seasonal trend has been underlined in recent years. The remaining variation is minor, indicating that trends and seasons account for most variations. This data is useful for businesses to forecast demand changes and for policymakers to consider when developing housing rules, such as giving incentives for a balanced construction schedule throughout the year.

- New affordable construction permits
  According to the data, there has been a recent drop in new affordable housing permits in Boston, which has been driven by economic and housing market conditions. The general trend is downward, while seasonal patterns indicate more permit issuance in warmer months, matching typical construction trends. Additional unexplained differences in permits could be caused by variables such as changes in government regulations or changes in land availability. Overall, the findings point to a decline in new affordable

housing permits, which could be connected to broader economic and housing market conditions.

3. Discussion:

- Logan Airport Travel Trends:
  The steady growing trend in both domestic and international passenger numbers at Logan Airport demonstrates a high demand for air travel. The observable pattern of rising in the summer and dropping in the winter months shows a predictable tendency that airport authorities and airlines may handle effectively. The airport can assure operational efficiency by aligning resources to accommodate busy seasons, such as increasing manpower and service capacity during the summer. Furthermore, persistent expansion in foreign flights demonstrates a continuing interest in air travel. Stakeholders should plan of time for this expansion, considering potential problems such as weather disruptions and special events.

- Boston's Hospitality business Insights:
  The Boston hotel business exhibits encouraging trends, most notably increased hotel occupancy rates. This has a consistent seasonal pattern, with peaks in the summer and lows in the winter. This information is useful for hotel managers because it allows them to modify their marketing and promotional tactics to increase profitability during slow periods. The rising trend in hotel pricing, particularly during the summer, reflects changing consumer choices and more competition. Hoteliers must adapt pricing tactics that consider both overall trends and volatility caused by global economic uncertainty. Understanding these relationships enables better revenue management.

- Labor Market Dynamics:
  An examination of the Boston job market reveals a troubling trend of job loss, which is most likely affected by variables such as automation, globalization, and the COVID-19 epidemic. Policymakers should be aware of these developments and explore strategic responses such as education investments and actions to boost domestic employment growth. The predicted increase in the unemployment rate in 2020 due to the pandemic necessitates adaptable workforce solutions to overcome unforeseen economic conditions. These findings emphasize the need of addressing structural challenges in the labor market to secure long-term economic growth.

- Real Estate and Construction Trends:
  The Boston real estate market is experiencing an increase in demand for units, with predictable seasonal variations. This knowledge is critical for maintenance and operations planning, allowing organizations to allocate resources more efficiently based

on seasonal demand patterns. The consistent seasonal drop in pipeline development costs provides a solid platform for cost analysis. Businesses can utilize this data to make more educated budgeting decisions, predict seasonal fluctuations, and precisely forecast future spending. Furthermore, the expansion of the construction industry, which is connected to increased energy demand and investments in renewables, highlights the necessity of monitoring seasonal job demand to support workforce planning.

- Housing Market Dynamics and Affordability:
  The Boston housing market exhibits a variety of trends, including decreasing foreclosure rates, lower median home prices, and higher sales. The increased affordability of housing helps to a stable housing market, allowing people to stay in their homes for longer periods of time. However, as seen by the drop in new affordable home permits, issues remain in the affordable housing industry. To solve these issues and ensure a balanced approach to house building throughout the year, policymakers should examine restrictions and propose incentives. Overall, these insights provide a thorough view of Boston's economic landscape, providing stakeholders with essential information to make informed decisions.

- Limitations:

  While the analysis gives useful insights into numerous economic indicators for Boston, several limits in the interpretation and application of the findings must be acknowledged.

  External influences and Events:
  > External influences such as global economic movements, geopolitical events, or unexpected catastrophes such as the COVID-19 pandemic can have a considerable impact on the observed trends. The research may not fully reflect the subtle effects of such externalities, making accurate long-term predictions difficult.

  Economic Modeling Assumptions:
  > Economic trends are complicated and can be impacted by a variety of factors. The analysis reduces the complexity by making assumptions and generalizations. Deviations from these assumptions may have an impact on the conclusions' correctness.

In summary, the analysis gives insight on significant economic trends in Boston, including travel patterns and the hospitality industry, as well as labor market dynamics and real estate developments. The findings emphasize both good and negative elements, providing stakeholders with useful information for strategic decision-making.

Despite the limitations mentioned above, the analysis is a significant tool for politicians, corporations, and researchers, providing a thorough picture of Boston's economic landscape.

4. Appendix A: Method

1. Data Collection:

   The dataset for this research was obtained from Analyze Boston, the City of Boston's open data hub. The dataset is titled "Economic Indicators," and it is a legacy dataset that spans the years January 2013 to December 2019. The Boston Planning and Development Authority (BPDA), which oversees planning and guiding equitable growth in the city of Boston, collects and maintains the data. The dataset includes economic information for tourism, hotel markets, the labor market, real estate development projects, and the housing market.

2. Variable Creation:

   Tourism
   logan_passengers: Number of domestic and international passengers at Logan Airport.
   logan_intl_flights: Total international flights at Logan Airport.

   Hotel Market
   hotel_occup_rate: Hotel occupancy rate for Boston.
   hotel_avg_daily_rate: Average daily rate for hotels in Boston.

   Labor Market
   total_jobs: Total number of jobs.
   unemp_rate: Unemployment rate for Boston.
   labor_force_part_rate: Labor force participation rate for Boston.

   Real Estate: Board Approved Development Projects (Pipeline)
   pipeline_unit: Number of units approved for development.
   pipeline_total_dev_cost: Total development cost of approved projects.
   pipeline_sqft: Total square feet of approved projects.
   pipeline_const_jobs: Number of construction jobs associated with approved projects.

   Real Estate Market: Housing
   foreclosure_pet: Number of foreclosure house petitions.
   foreclosure_deeds: Number of foreclosure house deeds.
   med_housing_price: Median housing sales price.
   housing_sales_vol: Number of houses sold.
   new_housing_const_permits: Number of permits for new housing construction.

new-affordable_housing_permits: Number of permits for new affordable housing construction.

3. Analytic Methods:

The analysis involved a combination of statistical, time series, and machine learning techniques to extract meaningful insights from the dataset.

1. Time Series Analysis:

   - Seasonal-Trend decomposition using LOESS (STL): Decomposition of selected numeric columns (excluding 'Year' and 'Month') into trend, seasonal, and residual components. This research sheds light on the underlying patterns and trends that have emerged throughout time.

   - ARIMA (Autoregressive Integrated Moving Average): The ARIMA model is used to forecast specified numeric columns. Based on historical data, this model predicts future values.

   - Long Short-Term Memory (LSTM) networks: LSTM network implementation for specified numeric columns. LSTM is a deep learning technique that is well suited for sequence prediction problems like time series forecasting.

2. Correlation Analysis:

   - Pairwise Scatter Plots: To visually analyze associations between variables, pairwise scatter plots were constructed for selected numeric columns.

   - Correlation Matrix: To quantify the linear correlations between variables, a correlation matrix was created for selected numeric columns.

   - Identification of High Correlations: Variables with high linear correlations (over a predetermined threshold) were selected and their correlation values were analyzed.

3. Insights from Scatter Plots:

   - Scatter plots were constructed to investigate correlations between pairs of columns with strong correlation, providing visual insights into potential economic indicator dependencies.

These methods enabled a thorough examination of the economic indicator's dataset, revealing temporal trends, forecasting capabilities, and inter-variable interactions. The use of classical time series analysis in conjunction with modern machine learning approaches enabled a comprehensive view of the economic landscape reflected in the dataset.

5. Appendix B: Results

5.1 Time Series Analysis

Seasonal-Trend Decomposition using LOESS (STL) :

To investigate the underlying patterns of several economic indicators, we performed a seasonal-trend decomposition. The graphs that result illustrate the original time series, trend, seasonality, and residual components. These visualizations offer useful insights into long-term trends and seasonal fluctuations in economic data.
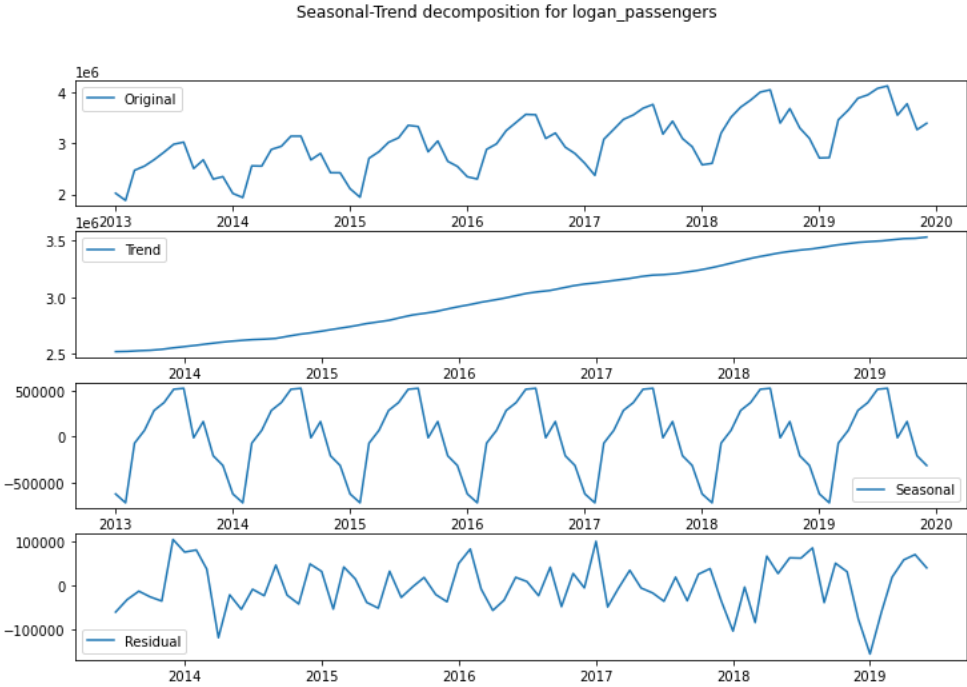
Autoregressive Integrated Moving Average (ARIMA):

ARIMA models were used to forecast the values of chosen economic indicators in the future. Mean Squared Error (MSE) was used to assess model accuracy. Forecasts can help us comprehend the potential paths of these indicators.

ARIMA Forecasting for logan_passengers (Best Order: (4, 1, 3), MSE: 74160716285.57)
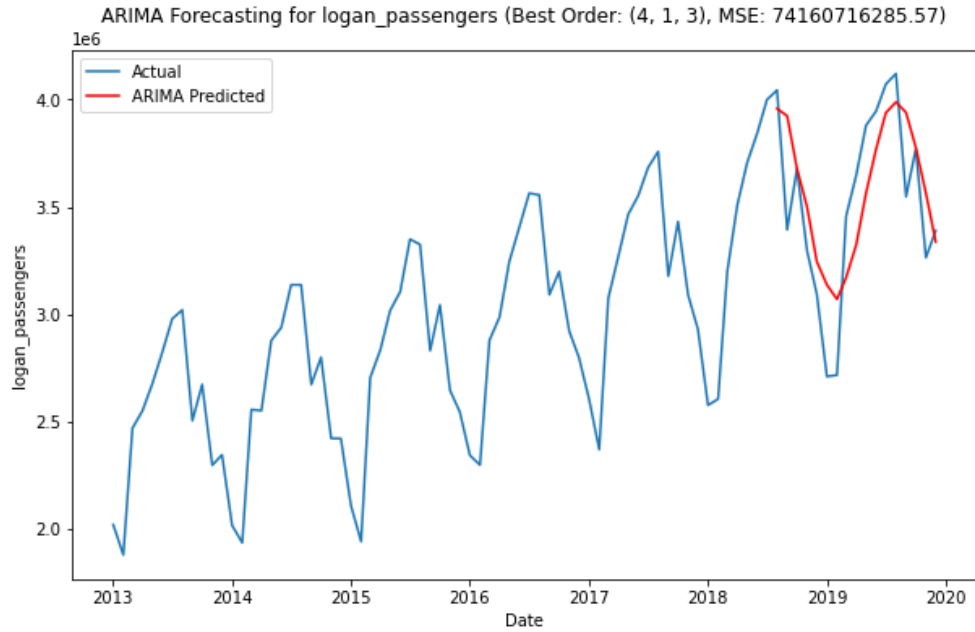
Long Short-Term Memory (LSTM) Networks:

To anticipate economic indicators, LSTM networks, a form of deep learning model, were used. On both training and test datasets, the LSTM models were trained and evaluated. The visuals show how accurate the LSTM predictions are when compared to the actual numbers.
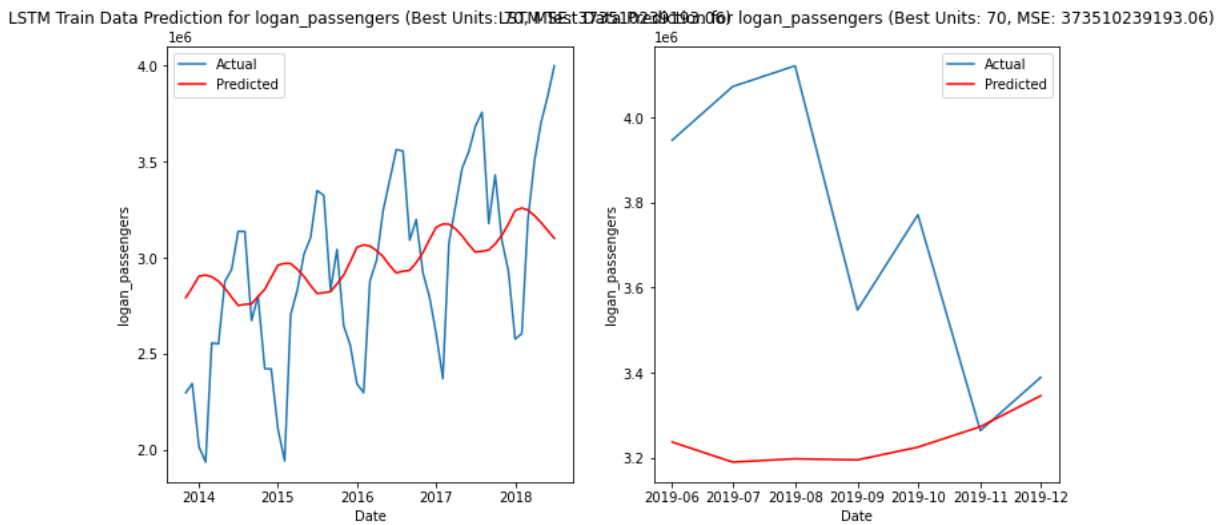
5.2 Pairwise Relationships and Correlation Analysis

Scatter Plot Pair plots:

To depict the pairwise correlations between selected economic variables, pair plots were created. These scatter plots provide an overview of the dataset's potential relationships and trends.
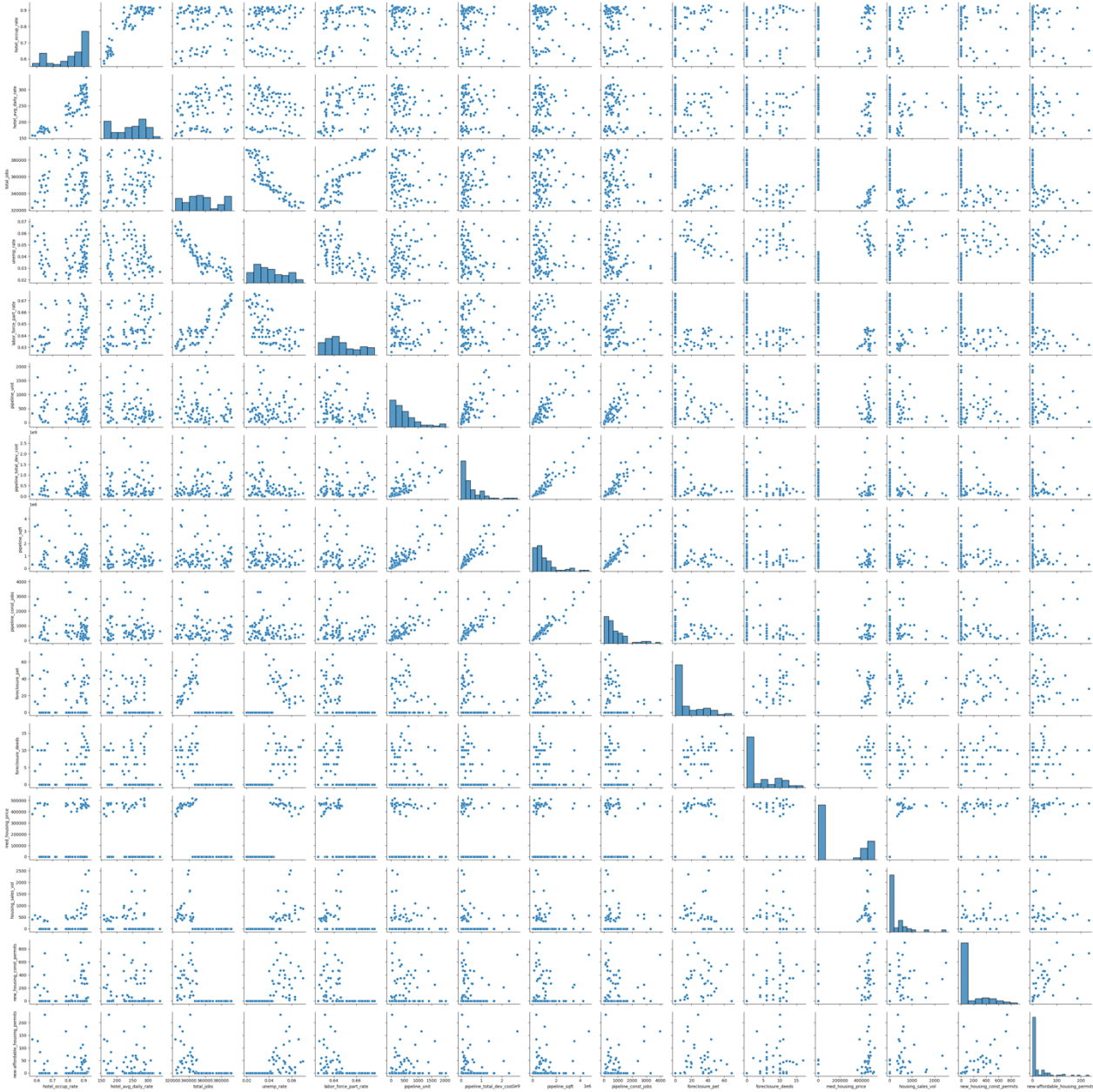
Correlation Matrix:

To quantify the linear correlations between economic variables, a correlation matrix was created. The heatmap visualization emphasizes the intensity and direction of correlations, assisting in the identification of relevant relationships.

Correlation Matrix

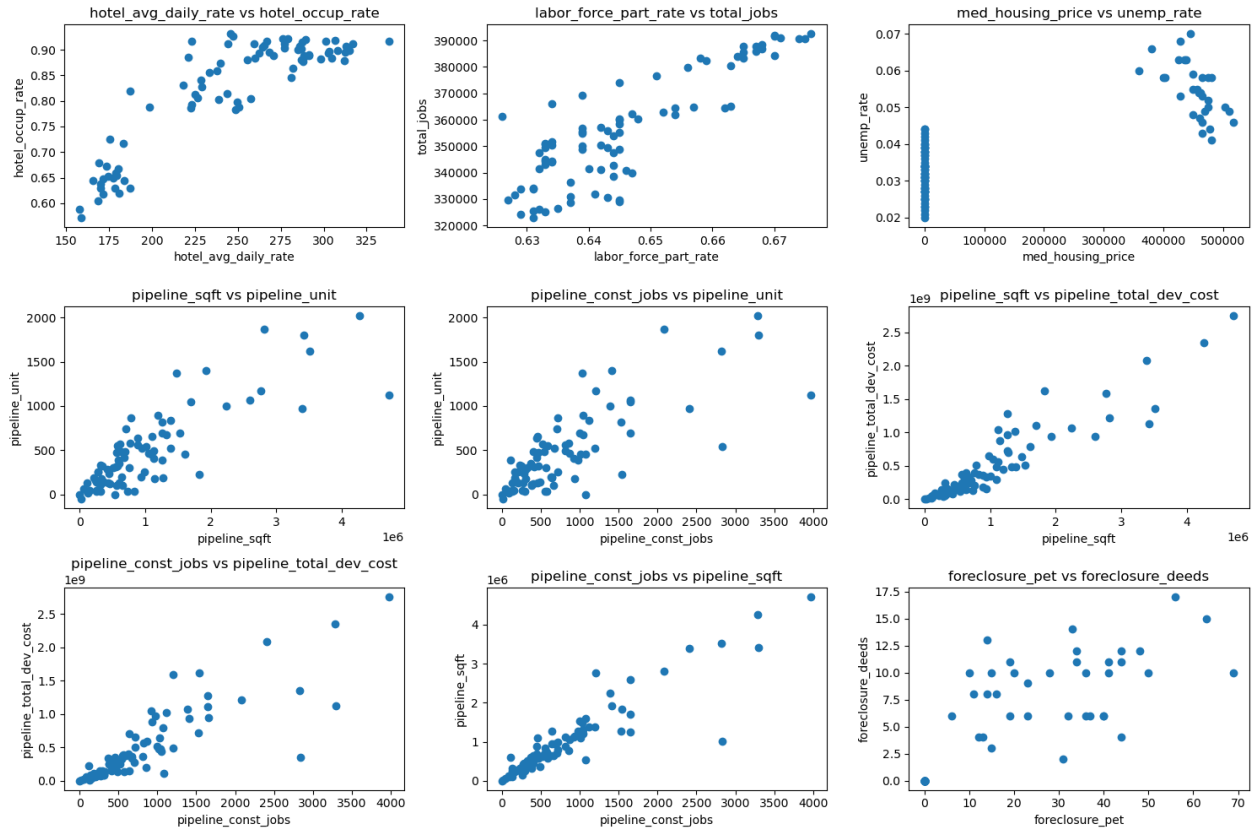|	hotel_occup_rate	hotel_avg_daily_rate	total_jobs	unemp_rate	labor_force_part_rate	pipeline_unit	pipeline_total_dev_cost	pipeline_sqft	pipeline_const_jobs	foreclosure_pct	foreclosure_deeds	med_housing_price	housing_sales_vol	new_housing_const_permits	new-affordable_housing_permits
hotel_occup_rate	1.00	0.88	0.14	0.03	0.31	-0.15	-0.11	-0.15	-0.14	-0.09	-0.02	-0.03	0.16	0.01	-0.18
hotel_avg_daily_rate	0.88	1.00	0.31	-0.20	0.38	-0.18	-0.11	-0.14	-0.15	-0.14	-0.12	-0.23	-0.08	-0.05	-0.19
total_jobs	0.14	0.31	1.00	-0.87	0.86	-0.11	0.03	-0.06	-0.11	-0.57	-0.68	-0.76	-0.55	-0.55	-0.50
unemp_rate	0.03	-0.20	-0.87	1.00	-0.57	0.04	-0.07	-0.01	0.04	0.54	0.73	0.83	0.67	0.60	0.52
labor_force_part_rate	0.31	0.38	0.86	-0.57	1.00	-0.14	-0.00	-0.09	-0.11	-0.46	-0.47	-0.51	-0.28	-0.39	-0.39
pipeline_unit	-0.15	-0.18	-0.11	0.04	-0.14	1.00	0.71	0.84	0.79	-0.13	-0.06	-0.02	-0.09	0.03	0.10
pipeline_total_dev_cost	-0.11	-0.11	0.03	-0.07	-0.00	0.71	1.00	0.93	0.86	-0.22	-0.21	-0.08	-0.13	-0.00	0.09
pipeline_sqft	-0.15	-0.14	-0.06	-0.01	-0.09	0.84	0.93	1.00	0.92	-0.15	-0.13	-0.02	-0.09	0.04	0.15
pipeline_const_jobs	-0.14	-0.15	-0.11	0.04	-0.11	0.79	0.86	0.92	1.00	-0.15	-0.12	0.05	-0.06	0.01	0.25
foreclosure_pct	-0.09	-0.14	-0.57	0.54	-0.46	-0.13	-0.22	-0.15	-0.15	1.00	0.84	0.60	0.39	0.61	0.39
foreclosure_deeds	-0.02	-0.12	-0.68	0.73	-0.47	-0.06	-0.21	-0.13	-0.12	0.84	1.00	0.70	0.49	0.69	0.51
med_housing_price	-0.03	-0.23	-0.76	0.83	-0.51	-0.02	-0.08	-0.02	0.05	0.60	0.70	1.00	0.71	0.67	0.60
housing_sales_vol	0.16	-0.08	-0.55	0.67	-0.28	-0.09	-0.13	-0.09	-0.06	0.39	0.49	0.71	1.00	0.49	0.35
new_housing_const_permits	0.01	-0.05	-0.55	0.60	-0.39	0.03	-0.00	0.04	0.01	0.61	0.69	0.67	0.49	1.00	0.70
new-affordable_housing_permits	-0.18	-0.19	-0.50	0.52	-0.39	0.10	0.09	0.15	0.25	0.39	0.51	0.60	0.35	0.70	1.00

High Correlation Pairs:

Economic indicator pairs with substantial correlations were identified and investigated further. Scatter plots were created to visualize these associations.

Using time series methodologies, economic indicators research reveals trends and forecasts. Significant connections, such as hotel_avg_daily_rate - hotel_occup_rate, provide strategic insights for Boston's inclusive growth.

Finally, the in-depth examination of Boston's economic landscape reveals a subtle interaction of forces influencing the city's direction. The findings reveal both positive and worrying developments across a variety of industries. The constant expansion in passenger counts at Logan Airport, combined with an increase in foreign flights, demonstrates the city's strong desire for air travel. The hospitality industry in Boston is showing promising signals, with increased hotel occupancy rates and a regular seasonal pattern. However, the labor economy is facing issues, including a significant reduction in total jobs, which could be exacerbated by automation, globalization, and the COVID-19 pandemic. These fundamental concerns must be addressed by policymakers through deliberate investments in education, domestic job development, and infrastructure.

The real estate and construction sectors exhibit dynamic tendencies, with rising unit demand, shifting development prices, and a constant increase in construction jobs. These insights give useful information for businesses and policymakers to properly navigate seasonal variations. Furthermore, the housing market is uneven, with dropping foreclosure rates, reduced median

home prices, and rising sales. Nonetheless, the decline in new affordable housing permits points to the necessity for focused actions to address affordability issues. Overall, this research provides stakeholders with critical information to make informed decisions about Boston's economic future, while considering the intricacies and external variables that drive its trajectory.

6. Appendix C: Data and Code

Below is the link for code:

https://github.com/bhanuprasadthota/MTH-522-Project-3

7. References

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8. Contributions

Bhanu Prasad Thota made a substantial contribution to the team's research by completing a thorough time series analysis with Seasonal-Trend Decomposition utilizing LOESS (STL). His ability in identifying underlying patterns and trends in economic indicators provides vital insights into Boston's economic landscape, enabling stakeholders to make informed decisions based on temporal trends and seasonal changes.

Naga Venkata Lokeswarao Maturi was instrumental in forecasting economic indicators with Autoregressive Integrated Moving Average (ARIMA) models. His work projecting future values assisted the team in understanding probable trajectories for various economic components,

providing a forward-looking perspective necessary for strategic planning. Naga's experience in time series forecasting greatly aided the team's analytical capacities.

Mantena Harsha Vardhan Varma applied his machine learning expertise, particularly in the implementation of Long Short-Term Memory (LSTM) networks. Mantena improved the team's capacity to reliably predict economic indicators by applying deep learning techniques to the dataset. His approach gave stakeholders a more sophisticated view of the dataset, allowing them to better understand the intricacies of Boston's economic trends.

Lakkamraju Hitesh Kashyap Varma was instrumental in the correlation analysis, which investigated pairwise correlations between economic factors. Lakkamraju found high correlation pairs using scatter plots and correlation matrices, shedding light on crucial linkages within the dataset. His study helped stakeholders in Boston gain a better grasp of how multiple economic forces interact, driving strategic decision-making.

We as a team conducted in-depth time series analysis, forecasting, and correlation studies to uncover trends and relationships in Boston's economic indicators. This collaborative effort resulted in insights for stakeholders, aiding strategic decision-making based on accurate predictions and a nuanced understanding of the city's economic landscape.