Demographic Dynamics and Urban Planning: Analyzing Population Growth Trends in the Four Asian Tigers

Enzo O. Taslim, Febryano H. Detesta, Gandhi P. Perwira, Liora L. Theadora, Yong C. Xuan

Abstract — The Four Asian Tigers—Hong Kong, Singapore, South Korea, and Taiwan were facing significant economic growth and rapid industrialization between the 1960s to 1990s, with annual growth rates surpassing 7%. This report will find out population growth in these regions and its relevance to urban planning and construction. The main purpose is to analyze and forecast population trends, which are critical for the effectiveness of infrastructure planning, resource management, and policy-making in densely populated areas. This project exploits some of the various analytical methods, such as forecasting, sensitivity analysis, and probabilistic modeling, to identify the factors driving population changes. By employing data-driven approaches, this study aims to provide clear insights into growth patterns and their implications for urban development. These methods are designed to enhance the accuracy of predictions and offer a deeper understanding of population dynamics. The findings will assist urban planners and policymakers in aligning infrastructure investments and policies with future population trends. Additionally, the study contributes to discussions on sustainable urban growth by emphasizing the importance of preparing for demographic shifts with appropriate resources and infrastructure. In conclusion, this project seeks to improve understanding of population trends in the Four Asian Tigers and provide actionable insights for strategic urban planning. It highlights the importance of linking demographic analysis with the development of sustainable, well-planned cities in fast-growing economies.

Impact Statement — This report underscores the critical interplay between population dynamics and urban planning in the Four Asian Tigers. By analyzing population growth trends, we provide essential insights that can help policymakers and urban planners develop sustainable strategies for infrastructure development and resource allocation, ensuring these regions can effectively adapt to future demographic changes.

I. INTRODUCTION

Population growth is a critical factor that significantly impacts infrastructure development, resource allocation, and urban planning, particularly in rapidly urbanizing regions. The Four Asian Tiger - Hong Kong, Singapore, South Korea, and Taiwan have experienced remarkable economic growth and industrialization over the past decades, accompanied by substantial population changes. Understanding the changes in population growth in these countries is essential for construction engineers, policymakers, and city planners to make informed decisions and effectively address the challenges related to these rapid dynamics.

This project aims to apply advanced AI techniques, specifically the use of Python, to analyze and model population growth trends in the Asian Four Tigers. We employ three mathematical models including Exponential Growth, Polynomial, and Gompertz, the study seeks to analyze and forecast future population trends up to the year 2053. The models are evaluated based on their Mean Square Error (MSE) which works as well as an objective measure of model performance [1], which determines the most accurate representation of the population data for each country. Furthermore, Monte Carlo simulations are changes or growth that do not occur in some strictly predefined ways but are defined on the sequence of random numbers generated during the simulation [2]. Using this method provides a range of possible future outcomes to account for uncertainties.

This research will have significant implications for construction engineering and urban planning for the Four Asian Tigers. The insight gained will inform infrastructure development, resource allocation, and policymaking to tackle the challenges shown by evolving demographic patterns. According to a comprehensive and systematic approach, this project will provide particle skills in data manipulation, model implementation, and effective data visualization, ultimately contributing to a better understanding of the demographic changes impacting the construction industry and urban development in these rapidly urbanizing regions.

II. STATISTICS

A. Concepts

The project applies different analytical methods to model the growth of population in the Four Asian Tigers, namely Hong Kong, Singapore, South Korea, and Taiwan, using Monte Carlo simulation, logistic growth modeling, sensitivity analysis, and machine learning. This project is thus structured around several code segments that implement these concepts, each contributing to a comprehensive understanding of population dynamics in these rapidly urbanizing regions.

The first part of the project is loading population data from a CSV file and filtering it to show only the Four Asian Tigers. The data is then transposed so years will be columns, and countries will be rows. The script defines an exponential growth model, a polynomial model, and a Gompertz model. These models are fitted to the historical population data of each country using the curve_fit function from the SciPy library. The fitted models are then used to predict future population trends over the next 30 years, and the results are visualized in subplots for each country, which enables clear comparisons among the different growth models against actual population data.

The second part provides a class, AIPopulationTrendPrediction, with a logistic growth model implemented therein to simulate population dynamics. This class predicts population trends based on the initial population, growth rate, carrying capacity, and time. The population data is generated using a logistic growth function that is used for predicting the future trend employing a linear regression model. Noise is added to the model to simulate real-world variability, and results are visualized to compare actual versus predicted population sizes.

Logistic growth modeling is further explored in this third segment by defining another class called population growth. The class defines methods to carry out Monte Carlo simulations, which introduce random variations in the growth rate and carrying capacity to examine how much the final population outcomes would vary. The results of such simulations are visualized using histograms that present the range of possible future populations based on the stochastic nature of the input parameters.

The fourth section of this project is sensitivity analysis; one looks at how changing the growth rate affects the size of the final population. By adjusting the growth rate by a small amount above and below its original value, the project examines how sensitive the population outcome will be concerning changes in this parameter. This is presented in bar plots: the relation between growth rate variations and final population sizes.

Besides that, it includes the extraction of historical stock data via finance, cleaning, and preparation for training a linear regression model to predict stock returns based on lagged returns. This part shows the application of machine learning techniques in financial data analysis and, at the same time, the adaptability of the methods used within the project.

Finally, the project brings about a basic income and expense tracker, which accepts financial input from the user to show a summary of income, expenses, and remaining balance. While this section is not relevant to population modeling, it serves to demonstrate practical skills in programming by building user-interactive applications.

It systematically integrated logistic growth modeling, Monte Carlo simulation, sensitivity analysis, and machine learning to create an overarching framework for comprehensively characterizing the population dynamics in the Four Asian Tigers. This integrative approach offers appreciable value to construction engineering, urban planning, and policymaking within a rapidly urbanizing region.

A Monte Carlo simulation is a statistical technique based upon random sampling and probability distribution for the modeling and analysis of complex systems with phenomena that cannot be distinctly predetermined. The basic steps of the Monte Carlo method include generating large numbers of random inputs for the uncertain variables of interest within a given model, to cover all possible outcomes for that model. This is especially beneficial when one needs to analyze phenomena for which conventional deterministic models cannot cope with variability and uncertainty associated with real-life situations. It usually starts with the selection of appropriate probability distributions for each random variable, since the distribution of a normal, uniform, or triangular variable may be too simple to model the nature of the data under consideration. Since this is a model, iteration will go into sampling different random variations that will result in a distribution of possible outcomes. This therefore gives a broad view of what the system's possible futures are, hence giving the decision-makers a basis on which to make scientifically-based assessments of risks and decisions on the likelihood of the various alternative scenarios.

In the case of population growth modeling, for instance, Monte Carlo simulation can be an ingredient of various sorts of mathematical models intended to predict future trends. This consists of general models, such as the exponential growth model, assuming a constant rate in the terminal sharp surge in the population size; the polynomial model, fitting a polynomial to the observed data to enable more complex growth dynamics; and the Gompertz Model, exhibiting typical S-shaped growth for those populations starting very slowly, followed by a period of rapid proliferation that finally stabilizes around the limits set by the environment. The integration of these models into Monte Carlo simulation enables the researcher to come up with numerous scenarios of demographic outcomes, each differing in assumptions over growth rates and other controlling factors. About criteria such as a Mean Square Error, the predictive capability of the models will be defined by the average of the squares of differences between the real and estimated values. Monte Carlo simulation certainly presents a comprehensive framework to understand and deal with the intricacies developed by uncertain systems, giving very useful insights that could extremely mark strategic planning and decision-making in various fields, ranging from urban development to resource management.

B. Models

- Data Loading and Preprocessing:
    a. The project begins by loading population data from a CSV file using the pandas library. The data is filtered to include only the four specified Asian Tiger countries.
    b. The data is then transposed so that years become the index (rows) and countries become the columns. This format is more convenient for analysis and plotting.
- Mathematical Models: The project employs three different mathematical models to fit the population data:
    a. Exponential Growth Model:
        i. This model assumes that the population grows continuously at a constant rate, which is often applicable in the early stages of population growth.
    b. Polynomial Model:
        i. This model can capture more complex growth patterns, including acceleration and deceleration in population growth.
    c. Gompertz Model :
        i. The Gompertz model is often used in biological contexts and is characterized by an initial exponential growth phase that slows as the population approaches the carrying capacity.
- Model Fitting:
    a. The curve_fit function from the scipy.optimize module is used to fit each model to the population data. This function estimates the parameters of the models by minimizing the difference between the observed data and the model predictions.
- Visualization:
    a. The project uses matplotlib to create subplots for each country, displaying the real population data alongside the fitted models. Each subplot includes:
        i. Scatter points for the actual population data.
        ii. Lines representing the predictions from the exponential, polynomial, and Gompertz models.
        iii. Titles, labels, legends, and grid lines for clarity.
- Summary of the Workflow:
  i. Load and Filter Data: Load population data from a CSV file and filter it for the four Asian Tiger countries.
  ii. Transpose Data: Change the structure of the DataFrame to facilitate analysis.
  iii. Define Models: Create functions for the exponential, polynomial, and Gompertz models.
  iv. Fit Models: Use curve fitting to estimate model parameters based on the historical population data.
  v. Predict Future Values: Extend the years and use the fitted models to predict future population growth.
  vi. Visualize Results: Plot the actual data and model predictions for each country in subplots

C. Algorithm & Flow-charts

1. Import the data on population in the CSV and filter the rows to the four Asian Tiger countries.
2. Transpose of the DataFrame to get years as columns and countries as rows.
3. Define the exponential growth model, polynomial model, and Gompertz model, functions:.
4. Define the subplot structure, then iterate over the countries, fitting and plotting the models.
5. Pull demographic data for the country, standardize the years and then use curve_fit to fit the three models.
6. Predict the future population for the next 30 years for each model using.
7. Create subplot and plot real data, exponential model, polynomial model, and Gompertz model.
8. Initialize the class AIPopulationTrendPrediction with initial population, growth rate, carrying capacity, and time.
9. Generate population data using the logistic growth model.
10. Prepare the dataset to train and build the arrays X and y.
11. Train a Linear Regression model on X_train and y_train.
12. Now, using a trained model, predict and compute the Mean Squared Error.
13. Plot the predicted population growth.
14. Start the PopulationGrowth class with an initial population, growth rate, carrying capacity, and duration.
15. Generate population data using the logistic growth model.

16. Perform sensitivity analysis by changing the growth rate, and plotting the final population.
17. Perform a Monte Carlo simulation: Change the growth rate and carrying capacity, then plot a histogram of the distribution of the final population.

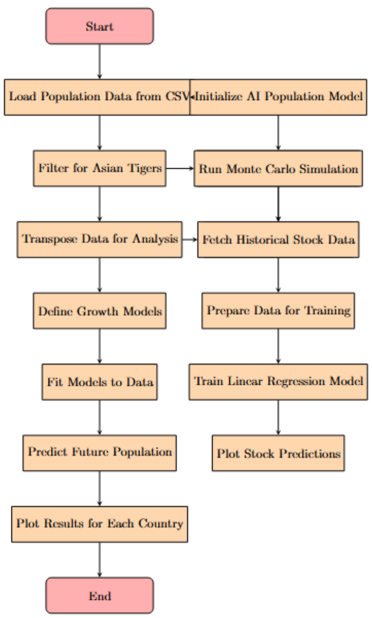
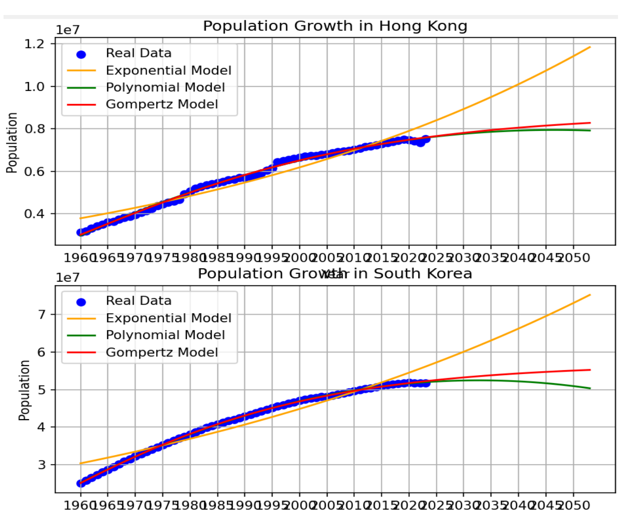


Fig. 1. Flowchart model showing the process of obtaining the results for population and GDP growth using different models.

III. RESULTS AND ANALYSIS

A. Simulation Results



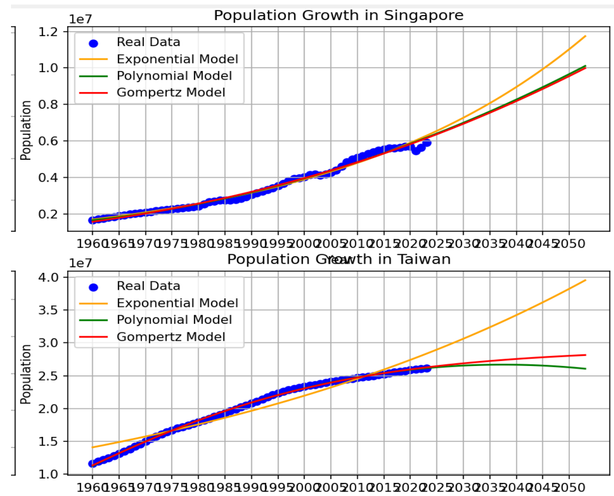


Fig. 2. Exponential model, Polynomial model, and Gompertz model of population growth from 1960 with simulations to 2054 compared to real-world population data obtained from World Bank [3] in Singapore, Taiwan, Hong Kong, and South Korea.

The model illustrates the population growth of Hong Kong, Taiwan, Singapore, and South Korea. Within the graph are three predictive models: Exponential Growth, Polynomial, and Gompertz. Each model utilizes a unique mathematical methodology to depict population patterns, with their forecasts displayed as dashed lines; through a comparative analysis of these models, we can assess their respective merits, constraints, and relevance to the demographic data of the Asian Tigers.

The X-axis points to the specific year (1960-2054) and the Y-axis points to the population for each of the years (in 10,000,000) The results of the simulations for each model are different, with the Exponential model being the most inaccurate model when compared to the real-world data.

B. Performance Analysis and Performance Metrics

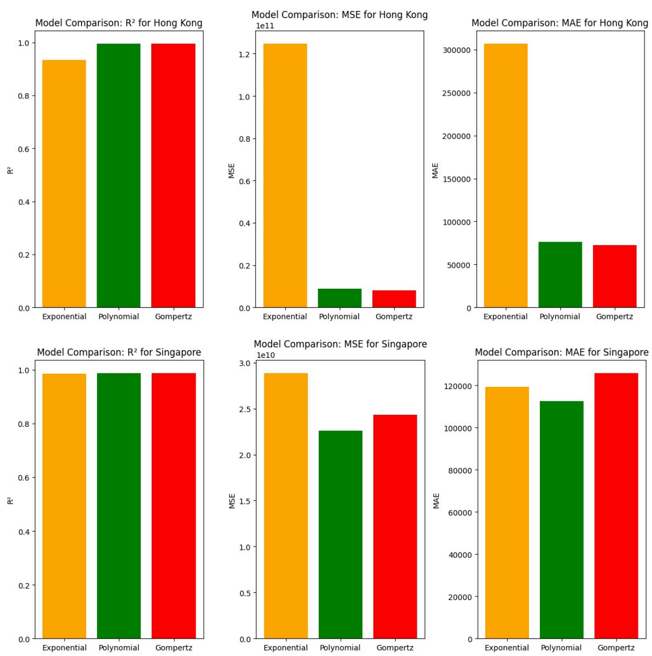
The inaccuracy of the Exponential model may be caused by oversimplifying the model for long-term population modeling due to it ignoring external conditions and assuming a constant growth rate. The Gompertz and Polynomial simulation produces a very similar result with both models fitting the curve for real-world data. Theoretically, when simulating population growth, particularly when anticipating a population reaching a saturation point because of resource constraints, the Gompertz model is typically more suitable. This model offers a realistic portrayal of growth patterns and is extensively employed in biological research [4].

To know how well the model predicts an outcome, we can calculate the coefficient of determination (R^2) which has the formula as shown in the picture.

$$R^2 = 1 - \frac{SSE}{SST} = 1 - \frac{\frac{1}{n}\sum_{i=1}^{n}\left(y^{(i)} - \hat{y}^{(i)}\right)^2}{\frac{1}{n}\sum_{i=1}^{n}(y^{(i)} - \bar{y})^2} = 1 - \frac{MSE}{Var(y)}$$

Fig. 2. Coefficient of determination formula.

R^2 values between 0 to 1. If the error of the model is small, the value becomes closer to 1. In this case, we can know that the model is perfect if the value of R^2 is 1. By using r2_score from sklearn.metrics we can find the coefficient of determination easily. For Hong Kong, the best model to use is the Gompertz model because the coefficient of determination is 0.9957, and the Polynomial model is at a close second with 0.9952. However, for Singapore, South Korea, and Taiwan, the best model to use is the Polynomial model, with R^2 valued at 0.9876, 0.9997, and 0.9984 respectively. By comparing our theory and calculation, we can know that they contradict each other, as theoretically, the Gompertz model is supposed to be more accurate in predicting population growth, but in our calculation, the polynomial model seems to have a higher coefficient of determination for most countries.



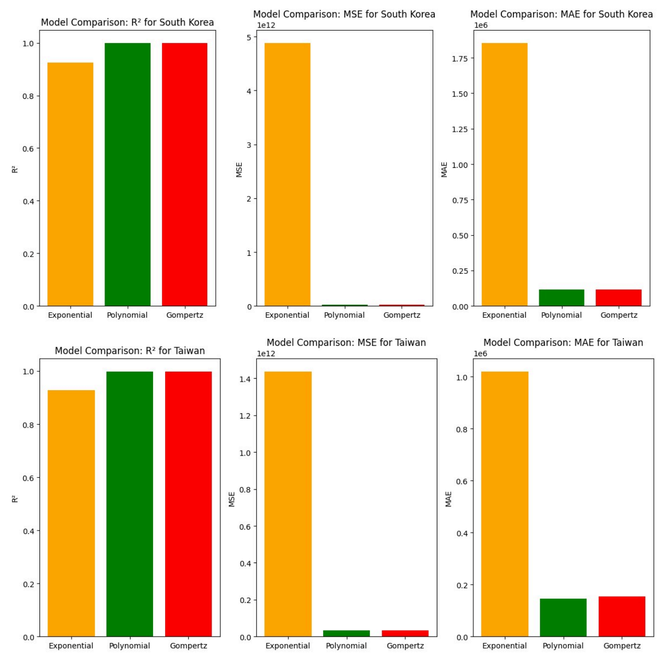


Fig. 3. Graph showing the R^2, MSE, and MAE of exponential, polynomial, and Gompertz models for Hong Kong, Singapore, South Korea, and Taiwan.

To further understand the accuracy of each model, we can utilize visual presentations of the calculations for R^2, MSE, and MAE. It is clear from the graph that the coefficient of determination for the exponential model is not as high as the other models, meaning that it is less precise. If the mean absolute error (MAE) and mean squared error (MSE) are high, that means the model has many errors. This shows that the simulations using the exponential model have the most errors. Therefore, we can conclude that for Hong Kong it is best to use the Gompertz model, and for the other three countries it is best to use the polynomial model.

C. *Comparative Graph and Comparative Analysis*

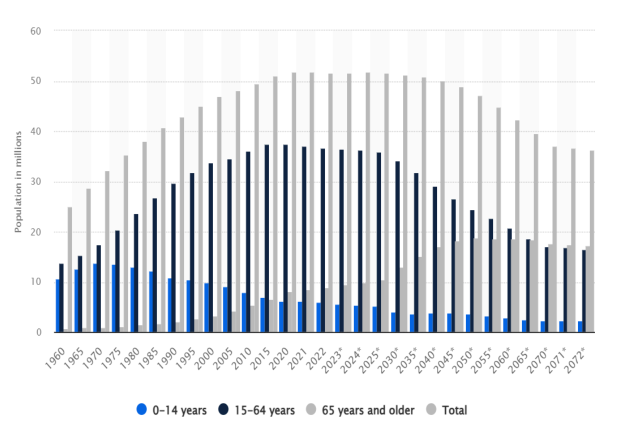


Fig. 4. Graph showing the population in South Korea from 1960 and projections to 2072 with grouping by age [6].

Compared to our simulation using the Gompertz, Polynomial, and Exponential models that did not consider significant external variables that may impact the model output and prediction, this graph projects the population of South Korea based on real-world events. We can analyze from the graph, that the population of people aged 0-14 years in South Korea continues to drastically decrease over time, which implies that the decline of the birth rate in South Korea has influenced this prediction. In South Korea, the current crisis of low birth rate is underpinned by a multitude of factors, including the elevated expenses associated with living, particularly in housing and education, alongside a work environment that provides women with fewer benefits and reduced wages in comparison to men, leading to a scenario where numerous young South Koreans are deferring marriage and the establishment of a family [6]. However, our Polynomial model for South Korea is in line with the graph above in predicting the population of the country. We can see that the population growth in the Polynomial model starts slightly decreasing by the end, meaning that the total population will start reducing. The graph from the research also shows that when it starts to get closer to 2054, the population total will slightly drop. Therefore, our simulation using the Polynomial model is quite reliable as it is similar to graphs from research.

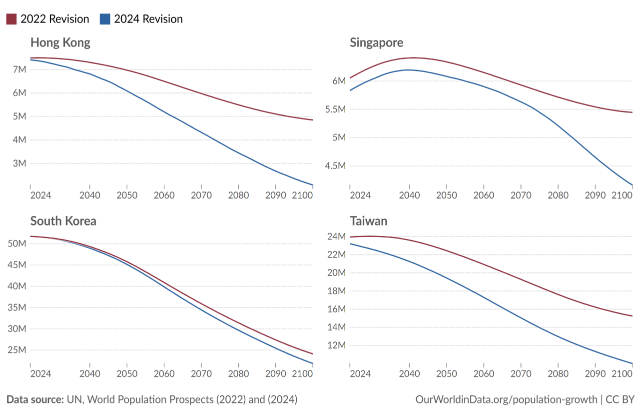


Fig. 5. UN population projections on Hong Kong, Singapore, South Korea, and Taiwan for 2024 to 2100 during 2022 and 2024 [7].

This data gives two projections, one from 2022 and the other from 2024, both have similar patterns but different numbers. The results of the projections over the years may change due to different input variables considered to determine the output. This chart presents a related trend with our three simulation models and the graph from the research (South Korea) where for Hong Kong, South Korea, and Taiwan, the population steadily lowers. Singapore's population projections consistently display that the country's inhabitants up until 2054 will not have a significant decrease. However, our simulation shows that Singapore will gradually increase throughout the years, while the UN's population projection conveys that it will start slightly dropping when it reaches 2040.

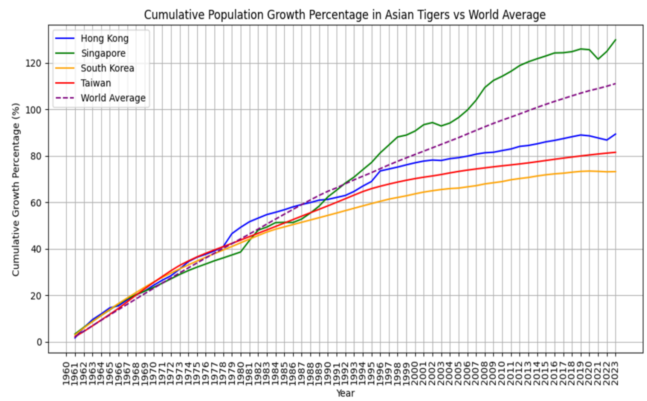


Fig. 6. Comparison line graph for the cumulative population growth percentage in Asia Tiger vs world average.

To further understand the distinction of the Asian Tigers population growth, we can compare it with the world average growth percentage. The trend observed from the graph is the increasing pattern in the cumulative growth percentage. Throughout the years, the line graph for each country is in line with the world average with continuous upward movement. However, the growth rate percentage for all countries excluding Singapore has decreased in recent years. This also gives the same conclusion as the other graphs we made a comparison with.

IV. IMPLEMENTATION OF ADDITIONAL COMPONENTS

A. *Sensitivity Analysis*

Sensitivity analysis offers insights into the relative importance of various input variables and presumptions within a model [8]. From the population growth simulation results, we know that there has been a reduction in recent years. This phenomenon may be attributed to a decline in the birth rate. For decades, high-income and upper-middle-income nations have maintained a total fertility rate beneath 2.1 births per woman, which is the critical replacement threshold that is instrumental in securing generational replacement within regions characterized by low mortality rates [9].

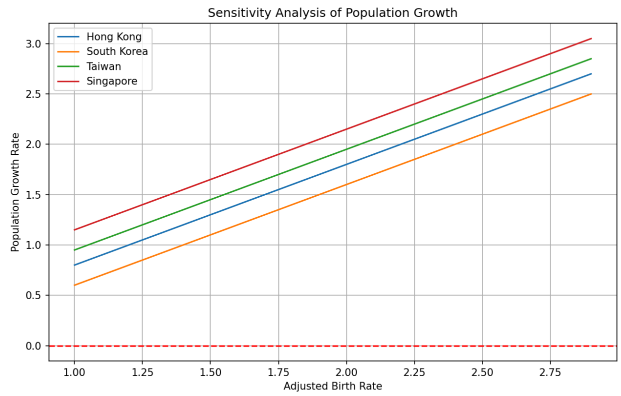


Fig. 7. Sensitivity analysis of birth rate for population growth in Hong Kong, Taiwan, South Korea, and Singapore.

The graphs presented illustrate the relationship between the adjusted birth rate and the population growth rate for four East Asian economies: Hong Kong, Taiwan, South Korea, and Singapore. This type of sensitivity analysis is crucial for policymakers and planners to understand the demographic dynamics and the potential implications of changes in birth rates. We projected the graph to know how different birth rates would affect the population growth rate in each country. The results have the same trend in which each country will have a linearly increased growth rate percentage if the birth rate rises.

The most notable feature of each line on the graphs is its steep slope, indicating a high sensitivity of population growth to changes in the adjusted birth rate. This suggests that even small fluctuations in the birth rate can have a significant impact on a nation's population growth.

By leveraging the insights from this comparative sensitivity analysis, policymakers in Hong Kong, Taiwan, Singapore, and South Korea can now know that birth rates affect the stability of population growth and can anticipate changes in the population total from birth rate data to make better policies in improving their infrastructure.

B. Economic Influences and Policy Implications

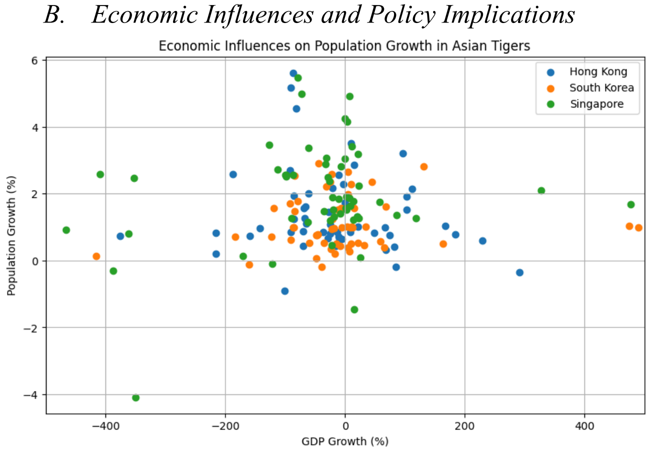


Fig. 8. Scatter plot of GDP Growth (%) to Population Growth(%) from 1960 to 2023

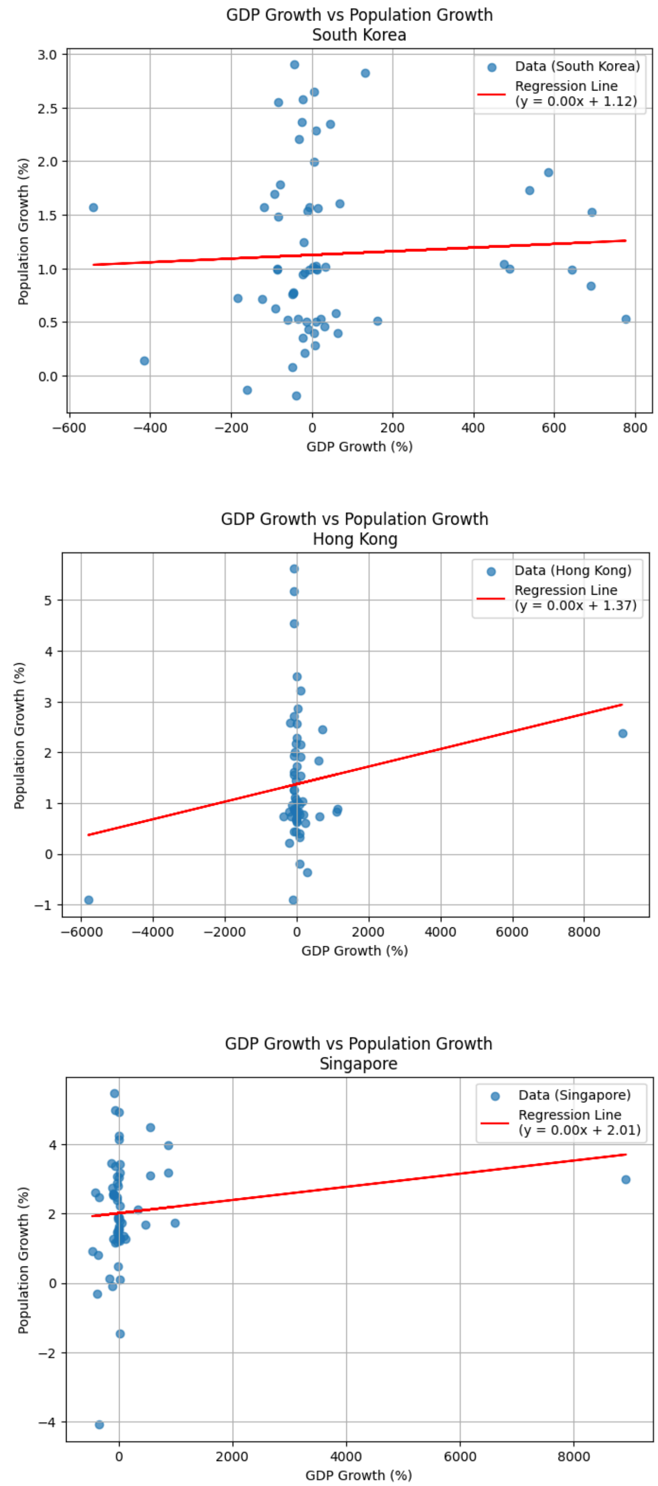


Fig. 9. Linear Regression Line of GDP Growth (%) to Population Growth(%) of Hong Kong, Singapore, and South Korea (PM2.5) from 1960 to 2023

The economic growth of Singapore, Hong Kong, and South Korea has garnered global attention, transforming these regions into vibrant economic powerhouses. Each has experienced remarkable development trajectories that have not only reshaped their economies but also significantly influenced their demographic landscapes. The scatter plots depicting the relationship between GDP growth and population growth for these three regions provide valuable insights into how these critical economic indicators interact.

In Singapore, the scatter plot reveals a concentration of data points with varying population growth rates, primarily clustered between 0% and 4%. This suggests that while Singapore has experienced significant economic expansion, it has not consistently translated into substantial increases in population. The regression line indicates a very shallow positive slope, implying that GDP growth has a minimal effect on population growth. The intercept suggests slight positive population growth even with negative GDP growth, reflecting a degree of demographic stability that is noteworthy. This stability can be attributed to Singapore's strategy marked by a holistic policy framework aimed at attracting a diverse range of stakeholders, including proficient expatriates, corporations, scholars, visitors, and global events [10].

Conversely, the scatter plot for Hong Kong shows more variability, with population growth values ranging from -1% to 5%. This indicates that economic conditions significantly affect demographic trends in the region. The regression line reflects a similar flat slope, suggesting that GDP growth does not strongly influence population growth. The intercept indicates positive population growth even during periods of negative GDP growth, but this is accompanied by significant fluctuations that reveal underlying vulnerabilities.

A global consulting firm's survey has revealed that Hong Kong tops the list as the costliest city for expatriates, with Singapore ranking second in terms of expenses [11]. High living costs, housing shortages, and social unrest contribute to this variability in Hong Kong's population growth. The presence of negative population growth during economic downturns highlights the precarious nature of Hong Kong's demographic landscape. Many residents face challenges related to affordability and quality of life, which can deter family growth and lead to emigration.

In contrast, South Korea presents a distinct case in the analysis of GDP growth and population growth. The scatter plot for South Korea shows a wider spread of data points, indicating more variability in population growth despite similar GDP growth rates. The regression line in this plot indicates a positive relationship between GDP growth and population growth, albeit with a shallow slope. This suggests that while there is some correlation, GDP growth has a minimal impact on population growth, which is particularly concerning given the context of South Korea's demographic challenges.

Low fertility rates and an aging population pose significant concerns for South Korea. The regression line's equation indicates that changes in GDP are associated with only slight increases in population growth. Factors such as urbanization, changing social norms, and economic pressures contribute to low birth rates, making it difficult for the country to maintain a stable population.

The scatter plots for Singapore, Hong Kong, and South Korea reveal a weak correlation between GDP growth and population growth, underscoring the different underlying factors influencing these trends. While Singapore's focus on attracting foreign talent has helped maintain a steady population, Hong Kong faces challenges that could lead to potential population decline, and South Korea grapples with low birth rates and an aging demographic.

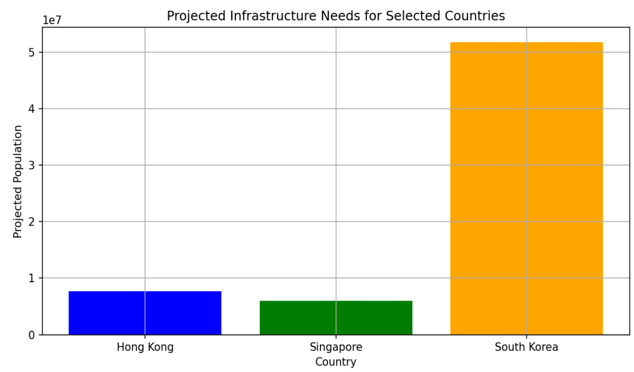


Fig. 10. Projected infrastructure needs for Hong Kong, Singapore, and South Korea

The graph presents a comparison of the forecasted infrastructure demands for Hong Kong, Singapore, and South Korea according to their projected population figures, demonstrating that Hong Kong exhibits the least estimated infrastructure needs, Singapore follows suit, and South Korea is anticipated to have the most substantial infrastructure requirements owing to its population surpassing 5 million.

Policymakers in all three regions must adopt comprehensive strategies that address not only economic growth but also the social factors influencing population dynamics. In Singapore, continued investment in family-friendly policies and affordable housing will be essential to encourage higher birth rates and improve overall quality of life. For Hong Kong, addressing the high cost of living, improving housing availability, and fostering a stable political environment will be crucial to retaining residents and attracting newcomers, particularly in light of recent socio-political challenges. In South Korea, initiatives aimed at improving work-life balance, supporting families, and encouraging immigration could help mitigate the effects of low fertility rates and foster a more favorable environment for family growth.

Ultimately, the insights from these scatter plots highlight the necessity for a holistic approach to integrate economic and demographic strategies. By understanding the unique challenges and opportunities presented by their respective economic and demographic landscapes, Singapore, Hong Kong, and South Korea can effectively navigate the challenges of aging populations and low birth rates. This approach will be vital for fostering sustainable growth and improving the quality of life for their citizens, ensuring that economic success translates into tangible benefits for all. By prioritizing policies that support both economic dynamism and demographic resilience, these regions can build a more balanced future that leverages their strengths while addressing their weaknesses.

C. Environmental Factors

The graph provides a visual representation of the long-term trends in cumulative pollution levels (PM2.5) for Four Asian Tigers: Hong Kong, South Korea, Taiwan, and Singapore, from 1960 to 2023.

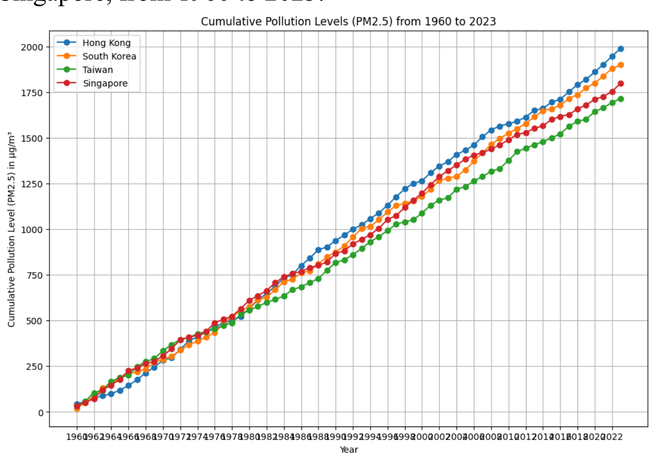


Fig. 11. Line graph of the cumulative pollution levels (PM2.5) from 1960 to 2023

At a glance, the most noticeable observation is the overall upward trajectory of the lines for all four countries, indicating a steady and significant increase in air pollution over the six-decade period. This trend suggests that the region has faced growing environmental challenges and pressures, likely driven by factors such as rapid industrialization, urbanization, and changes in energy consumption patterns.

By taking a closer look, the relative positioning of the lines reveals some interesting insights. Hong Kong appears to have the highest cumulative pollution levels throughout the time frame, with its line consistently above the others. This aligns with the city's reputation as a populous, highly developed economic center, which has historically grappled with air quality issues stemming from factors like vehicle emissions, industrial activities, and geographical constraints.

In contrast, South Korea's line appears to be the lowest among the four countries, indicating relatively lower cumulative pollution levels. This may reflect the country's efforts to address air pollution through policy interventions, technological advancements, and a gradual shift towards cleaner energy sources, although challenges likely remain.

The lines for Taiwan and Singapore are falling somewhere in the middle, with Taiwan's line trending closer to Hong Kong's and Singapore's line closer to South Korea's. This suggests that these two countries have experienced pollution challenges that are less serious than Hong Kong's but more pronounced than South Korea's, potentially due to differences in their respective economic and industrial profiles, as well as their geographic and demographic characteristics.

Importantly, the lines for all four countries do not exhibit a perfectly linear increase but rather show some undulation and variations over time. This indicates that the pollution levels were not consistently rising at the same rate but rather experienced periods of relative improvement or deterioration, potentially influenced by factors such as government policies, economic cycles, technological advancements, or even environmental events [12].

From a broader perspective, the graph serves as a valuable tool for understanding the long-term environmental trends in this region and highlights the urgent need for comprehensive and coordinated efforts to address air pollution. As these countries continue to develop and urbanize, managing the delicate balance between economic growth and environmental sustainability will be a critical challenge that policymakers, industries, and citizens must collectively address [13].

By examining the relative positions and trajectories of the lines, one can gain insights into the unique circumstances and challenges faced by each country, as well as identify opportunities for cross-border collaboration and the sharing of best practices in air quality management. Furthermore, the data and visualization provided in the graph can serve as a foundation for further research, policy analysis, and the development of effective strategies to mitigate the detrimental effects of air pollution on public health, ecosystems, and overall quality of life in these East Asian nations.

In conclusion, this graph offers a compelling visual narrative of the region's environmental evolution, underscoring the complex and persistent nature of air pollution challenges. As the world grapples with the global imperative of sustainable development, the experiences and lessons gleaned from this data can provide valuable insights and inspiration for other countries and regions seeking to address their environmental concerns.

D. *Stochastic Modeling Using Monte Carlo Simulations*

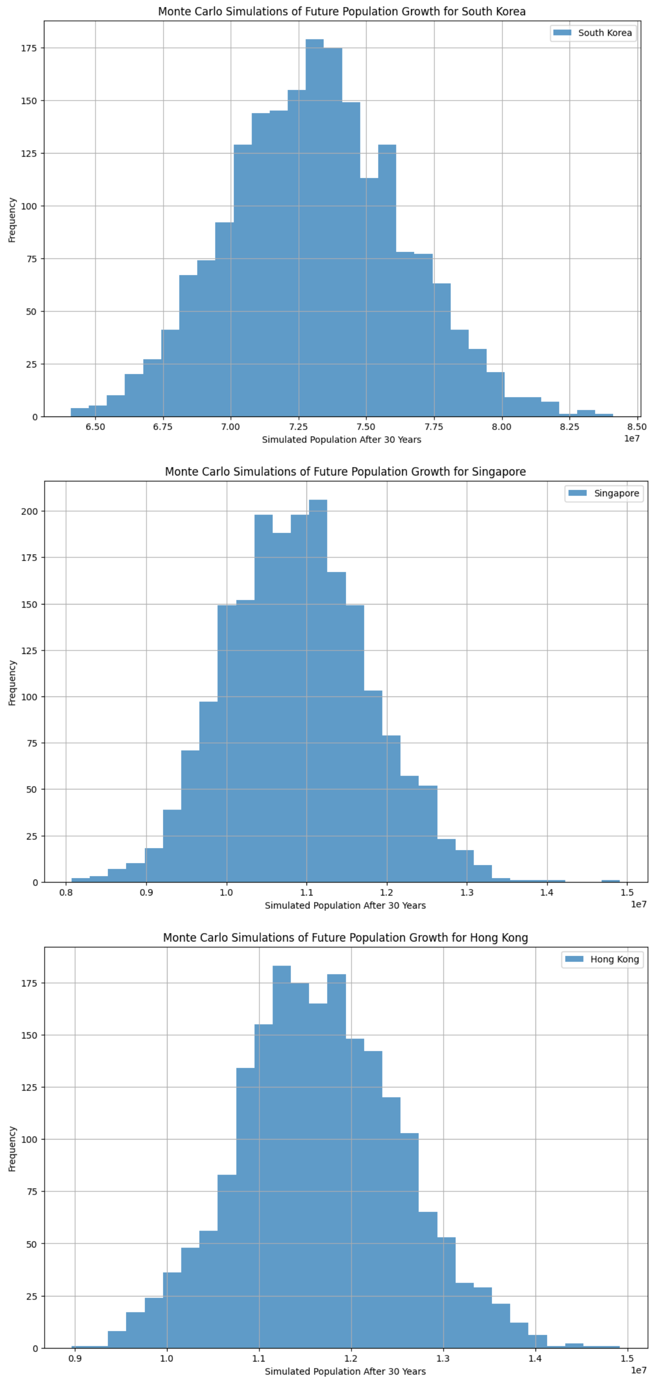


Fig. 12. Monte Carlo simulations of future population growth in the next 30 years for Singapore, South Korea, and Hong Kong.

Monte Carlo simulations are a powerful statistical tool that help model uncertainty in complex systems and predict potential outcomes through random sampling [14]. When applied to population projections, these simulations enable policymakers and researchers to evaluate a range of possible future scenarios, accounting for variations in birth rates, death rates, immigration, and economic growth.

The histograms for South Korea, Singapore, and Hong Kong illustrate the results of Monte Carlo simulations conducted over 30 years. Each histogram represents the frequency distribution of simulated population outcomes, providing insights into likely population levels and the uncertainties surrounding these projections.

In South Korea, the population distribution peaks around 7.3 million (7.3×10^7), with a range between 6.5 million and 8.5 million. The histogram is symmetric, resembling a bell curve, with most outcomes concentrated around the mean. This suggests a relatively stable projection for South Korea's population over the next 30 years.

However, South Korea's population growth is influenced by its low fertility rate, aging population, and modest immigration policies. While the peak at 7.3 million reflects a continuation of current demographic trends, the range of outcomes—with a lower bound of 6.5 million—highlights the challenges posed by its declining birth rate. Even under optimistic assumptions, population growth in South Korea appears limited.

The bell-shaped curve of the histogram indicates a high degree of predictability in the population projections. Yet, the lower tail of the distribution (below 7.0 million) suggests a non-negligible risk of population decline, driven by several factors. These include further declines in fertility rates and an aging population, which could exacerbate dependency ratios and strain healthcare and social services.

To mitigate risks associated with stagnating population growth, South Korea must encourage higher fertility rates through family-friendly policies, such as subsidized child care, parental leave, and financial incentives for families. Additionally, attracting immigrants by implementing policies that make South Korea a desirable destination for skilled workers is essential to address labor shortages and foster economic growth. Investing in automation and artificial intelligence can also help offset the economic impact of a shrinking workforce.

In Singapore, the population distribution peaks around 12 million (1.2×10^7), with a range between 9 million and 15 million. The histogram is wider than South Korea's, indicating greater uncertainty in the population projections, as the broader tails suggest a wider range of potential outcomes.

Singapore's population growth heavily relies on immigration due to its low natural birth rate. The peak of the histogram at 12 million reflects continued economic growth and robust migration policies. However, the broader distribution highlights the uncertainty surrounding future immigration trends and their impact on the population.

The lower tail of the distribution (below 10 million) points to potential risks, such as economic shocks that could reduce Singapore’s ability to attract foreign workers. Stricter immigration policies or increased competition for global talent could also lead to lower population growth. Conversely, the upper tail of the distribution (above 14 million) reflects the possibility of sustained economic growth and aggressive immigration policies, potentially resulting in a larger-than-expected population.

The variability in Singapore's population projections underscores the importance of maintaining open immigration policies to attract global talent and sustain economic growth. Improving housing affordability and urban infrastructure is crucial to accommodate a growing population while ensuring a high quality of life. Encouraging natural population growth through policies that support families, such as flexible work arrangements and subsidies for education and childcare, is also vital [15].

Hong Kong's population distribution peaks at around 12 million (1.2×10^7), with a range between 10 million and 15 million. The histogram is similar in shape to Singapore's, with a widespread indicating significant uncertainty in the population projections.

Hong Kong faces unique demographic challenges, including limited land availability, high housing costs, and geopolitical uncertainties. These factors influence both immigration and emigration patterns, contributing to the broader distribution of outcomes. The peak at 12 million reflects a continuation of current trends, but the lower tail of the distribution (below 10 million) highlights the risk of population decline.

Key factors driving this risk include the emigration of skilled workers due to ongoing geopolitical tensions and limited economic opportunities, as well as declining fertility rates, which further limit natural population growth. The upper tail of the distribution (above 14 million) suggests the possibility of a population increase driven by sustained economic growth and improved immigration policies.

To sustain its population growth and economic competitiveness, Hong Kong must address housing affordability to attract and retain talent. Diversifying its economy to reduce reliance on specific industries and create new growth opportunities is essential. Additionally, fostering innovation and entrepreneurship will help Hong Kong remain competitive in a rapidly changing global landscape. When comparing the three regions, South Korea exhibits the most stable population projections, with a narrower distribution centered around the mean. This reflects a high degree of predictability but also highlights the challenges of overcoming structural-demographic issues. In contrast, Singapore and Hong Kong show broader distributions, reflecting greater uncertainty in their population trajectories. This variability underscores their reliance on immigration and exposure to external shocks.

Both Singapore and Hong Kong are highly dependent on economic growth and immigration policies to sustain their populations. Any disruption to these factors could lead to significant deviations in their population outcomes. On the other hand, South Korea, while less reliant on immigration, faces challenges related to its aging population and low fertility rates, which could constrain long-term growth.

The wider spreads of the histograms for Singapore and Hong Kong highlight greater uncertainty, with both regions facing risks of population decline or stagnation under adverse conditions. Otherwise, population growth is slowed, and economic growth is further [16]. South Korea's narrower distribution suggests more predictable outcomes but also reflects the difficulty of achieving significant population growth under current trends.

The Monte Carlo simulations provide valuable insights into the potential population trajectories of South Korea, Singapore, and Hong Kong over the next 30 years. While South Korea's population growth appears relatively stable, it is constrained by low fertility rates and an aging population. In contrast, Singapore and Hong Kong face greater uncertainty, with their population outcomes heavily influenced by immigration policies and economic conditions.

E. Impact of Immigration

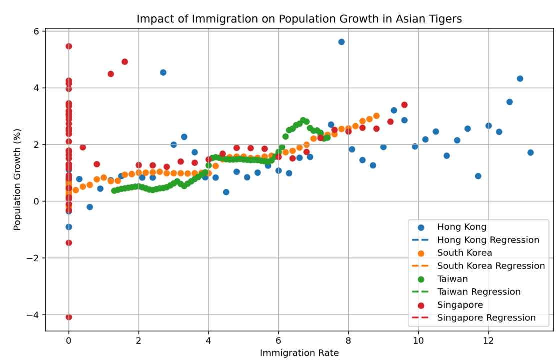


Fig. 13. Scatter chart of impact of immigration on population growth in Asian Tigers.

The graph presented provides a compelling visual representation of the intricate relationship between immigration rates and population growth in the prominent Asian economies, commonly referred to as the "Asian Tigers" - Hong Kong, South Korea, Singapore, and Taiwan. This data visualization offers a profound insight into the critical role that immigration plays in fueling the demographic and economic expansion of these highly successful nations.

At the core of the graph's message is the clear and positive correlation between immigration rates and population growth rates. The positive correlation between immigration rates and population growth observed in the graph suggests that the Asian Tiger economies are likely to experience a significant shift towards a more urbanized and educated society. This transition can lead to improved standards of living, greater economic competitiveness, and the emergence of a thriving middle class, as the influx of skilled immigrants and investment in education foster a more prosperous and innovative ecosystem [17]. As the immigration rate increases along the x-axis, we observe a corresponding rise in the population growth rates across all four countries, as evidenced by the upward-sloping regression lines. This fundamental relationship underscores the pivotal contribution of immigration in driving the remarkable demographic transformations witnessed in these Asian powerhouses. By attracting skilled labor, entrepreneurs, and talented individuals from around the world, the Asian Tigers have been able to harness the benefits of increased human capital and leverage it to propel their economic and social development. The influx of diverse perspectives, skills, and ideas has undoubtedly played a crucial role in fueling the innovation, productivity, and dynamism that have characterized in recent decades.

However, the graph also reveals intriguing divergences in the growth trajectories of the individual countries. While the overall trend is consistent, Hong Kong and Singapore appear to exhibit higher population growth rates compared to South Korea and Taiwan, even at similar immigration levels. These divergences highlight the importance of acknowledging the unique circumstances and drivers that shape the demographic dynamics of each nation. Such nuanced differences may be attributed to a variety of factors, including variations in immigration policies, economic structures, and social dynamics. Understanding these country-specific nuances is essential for policymakers as they navigate the complex task of managing population growth and immigration in a way that aligns with their national priorities and aspirations also introduced to the general rating and demonstrating less reliance on production data [18].

The insights gained from this graph pose significant implications for the policymaking landscape of the Asian Tigers. Governments must carefully balance the benefits of immigration-driven population growth with the potential challenges, such as strain on public services, housing shortages, and social integration concerns. A one-size-fits-all approach may prove inadequate, and a more tailored, context-specific strategy may be necessary to address the unique circumstances of each nation.

In conclusion, the graph's depiction of the impact of immigration on population growth in the Asian Tigers underscores the pivotal role that this phenomenon plays in shaping the demographic and economic trajectories of these highly influential economies. By recognizing the complexities and nuances inherent in this relationship, policymakers can work towards crafting more effective and sustainable policies that harness the benefits of immigration while mitigating its associated challenges. As the Asian Tigers continue to evolve and adapt to the global landscape, the insights gleaned from this graph will remain crucial in guiding their path forward.

F. Time Series Analysis

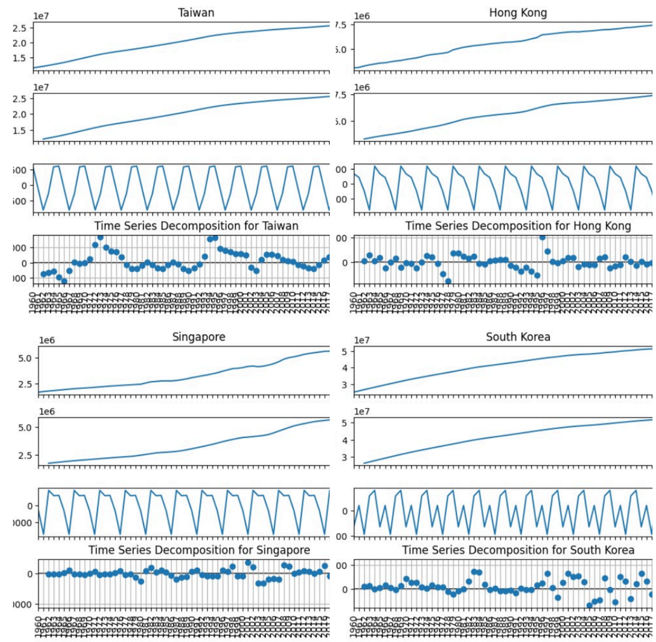
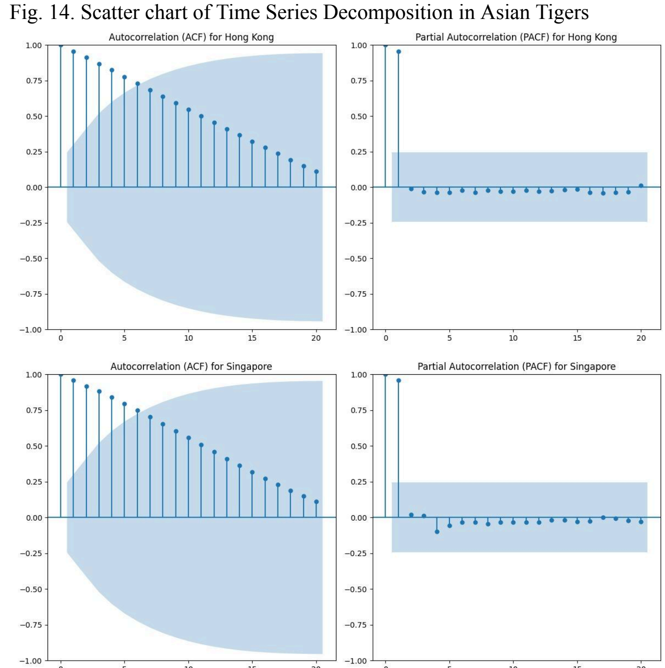


Fig. 14. Scatter chart of Time Series Decomposition in Asian Tigers



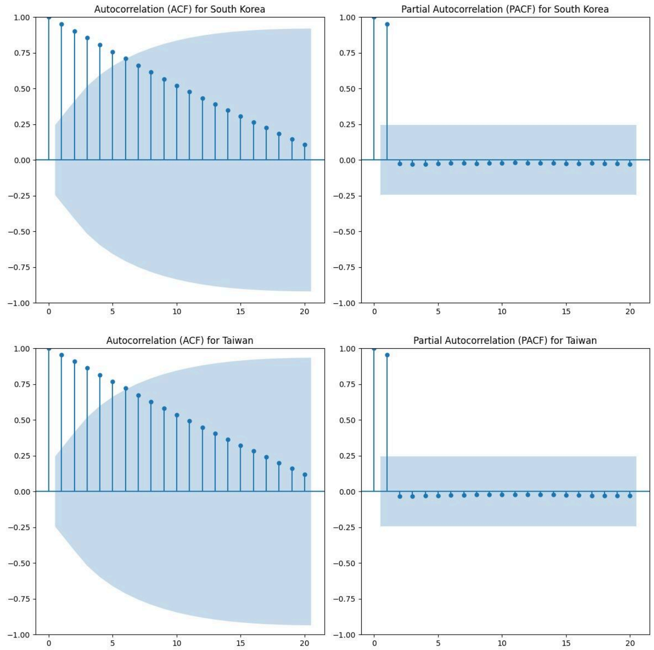


Fig. 15. ACF and PACF for Asian Tigers

Population growth is one of the most critical areas of study in economics, sociology, and public policy. The changes in population trends directly influence urban planning, healthcare systems, workforce dynamics, and resource allocation. Long-term time series are necessary to better understand population dynamics, assess species' conservation status, and make management decisions [19]. The "Asian Tigers", including Hong Kong, Singapore, South Korea, and Taiwan, serve as fascinating case studies when analyzing population trends due to their rapid industrialization, urbanization, and unique demographic transitions. This essay explores how advanced time series analysis can provide richer insights into their population growth patterns, using models such as Autocorrelation and Time Series Decomposition. By examining these methodologies, we aim to uncover new dimensions of population dynamics and offer a forecast of potential future trends.

The Asian Tigers have shared similarities in their trajectories of economic growth, yet their population dynamics differ due to geographical constraints, policy interventions, and cultural factors. Over the past several decades, all four nations have experienced significant shifts in population growth patterns. For instance, Hong Kong and Singapore, constrained by their small land areas, have seen a rapid but controlled population increase, driven by migration and urbanization. Meanwhile, South Korea and Taiwan, being larger and more industrialized, experienced mid-century population booms before growth slowed due to declining fertility rates and aging demographics.

Capturing these patterns through time series analysis can help us identify underlying trends, seasonal variations, and stochastic processes influencing population changes. Traditional models such as decomposition help isolate key components of a population time series—trend, seasonality, and residuals. However, more advanced techniques provide deeper insights into recurring patterns, potential future trajectories, and the factors driving them.

One of the simplest yet powerful tools in time series analysis is the moving average. By calculating averages over fixed intervals, this technique smooths out short-term fluctuations, allowing us to focus on long-term population trends. For the Asian Tigers, moving average analysis highlights the distinct phases of their population dynamics. For instance, a 5-year moving average illustrates short-term trends, such as the effects of migration spikes or social policies. In contrast, a 10-year moving average smooths over these variations to reveal broader changes, such as the gradual slowing of population growth in South Korea and Taiwan. In Hong Kong and Singapore, the moving averages demonstrate how population growth has plateaued in recent decades, reflecting the physical and infrastructural constraints of these city-states.By comparing short- and long-term moving averages, policymakers can identify key inflection points—periods when growth rates accelerated or decelerated—and assess the effectiveness of past interventions. For example, Singapore's population policies aimed at attracting skilled migrants can be seen in the upward trends of its moving average curves in the 2000s.

Autocorrelation (ACF) and partial autocorrelation (PACF) are statistical tools that measure the relationship between a time series and its lagged values [20]. For population data, these plots reveal whether past population values influence current values and can help identify seasonality or periodic trends.In analyzing the population data of the Asian Tigers, strong autocorrelation at lag intervals suggests that population changes are influenced by recurring factors, such as economic cycles or migration policies. For example, if the ACF plot for South Korea shows significant peaks at lag intervals of 5 or 10 years, it may indicate periodic fluctuations driven by policy changes or economic conditions. The PACF, on the other hand, isolates the direct relationship between a lagged value and the current value, removing the influence of intermediate lags. In the case of the Asian Tigers, PACF plots help confirm whether recent population trends are primarily influenced by short-term factors (e.g., migration trends) or longer-term demographic shifts (e.g., declining fertility rates).

Using the method of Time Series Decomposition can decompose time series into tendency, periodical, and remaining components [21]. Hong Kong and South Korea, the decomposition plots show relatively stable and consistent trends, with minor fluctuations in the seasonal and irregular components. Time series analysis highlights the urgency of addressing this issue through policies that support workforce participation, healthcare, and pensions. This suggests that the random forest forecasts for these countries are likely to capture the core long-term trends without being overly influenced by short-term volatility. In contrast, the time series decomposition plots for Singapore and Taiwan reveal more pronounced fluctuations in the trend, seasonal, and irregular components. This indicates that the underlying data for these countries exhibits higher levels of variability and complexity, which the random forest model may need to account for more explicitly in its forecasting approach. The differences in the time series decomposition patterns across the four countries suggest that the drivers and dynamics shaping their economic development are unique and may require tailored modeling and forecasting strategies.

Implications for Forecasting and Decision-Making, the time series decomposition insights can have important implications for how the random forest forecasts are interpreted and utilized by policymakers and stakeholders. For countries like Hong Kong and South Korea, the more stable decomposition patterns may provide greater confidence in the long-term forecasts, allowing for more robust strategic planning and decision-making. However, for Singapore and Taiwan, the increased volatility and complexity revealed in the decomposition plots may necessitate a more nuanced approach, with greater attention paid to short-term fluctuations and potential risks. Overall, the combination of the random forest forecasts and the time series decomposition analysis offers a comprehensive view of the economic trajectories of these Asia-Pacific economies. This information can inform policy decisions, investment strategies, and resource allocation to support sustainable and resilient growth in the region.

The population trends of the Asian Tigers offer a rich field for time series analysis, combining historical data with advanced models to uncover deeper insights. Moving averages and decomposition reveal long-term trends and seasonal patterns. This comprehensive approach to time series analysis not only illuminates the past and present dynamics of population growth but also equips policymakers with the tools to navigate future challenges. As the Asian Tigers continue to evolve, these insights will play a crucial role in shaping strategies for sustainable development, economic resilience, and social well-being.

G. What-If Scenario

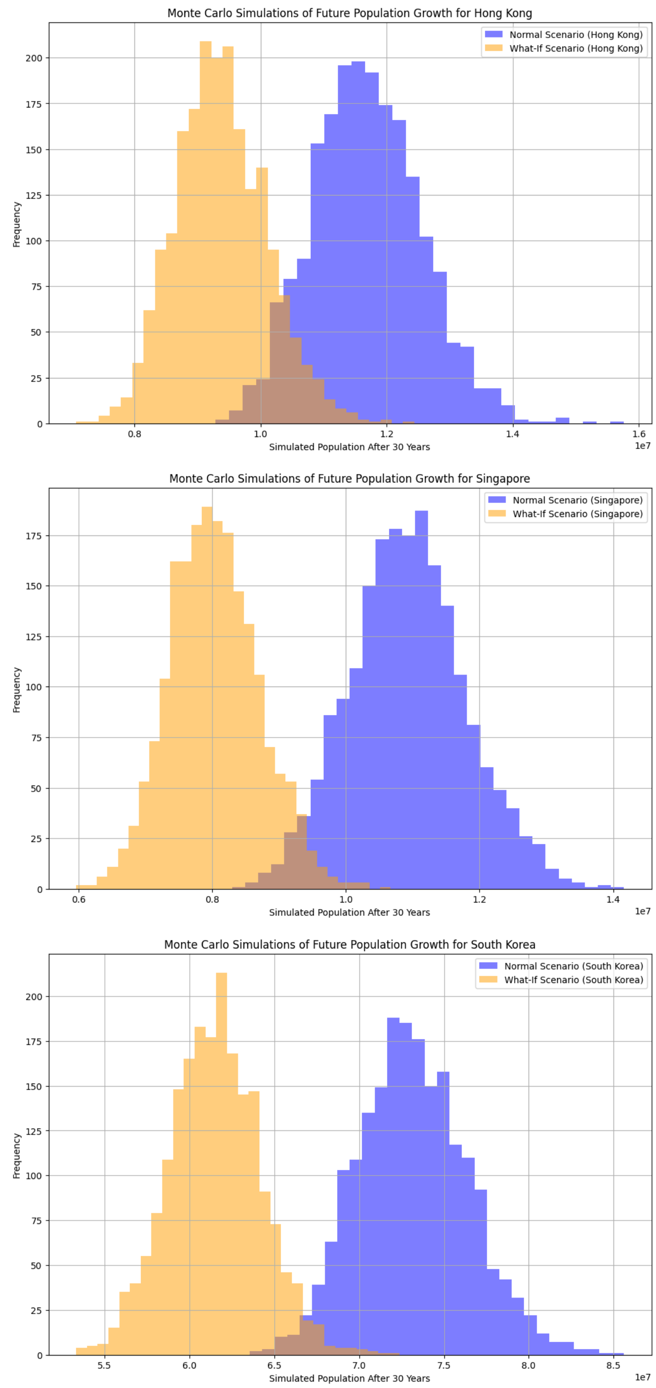


Fig. 16. Monte Carlo Simulations of Future Population Growth in normal scenario and what-if scenario for Singapore, South Korea, and Hong Kong.

The provided histograms depict the results of Monte Carlo simulations modeling population growth over 30 years for three regions: Hong Kong, Singapore, and South Korea. These simulations compare two scenarios: the Normal Scenario (blue), which assumes historical rates of

GDP growth and immigration, and the What-If Scenario (orange), where GDP growth and immigration rates are halved. This extended time horizon amplifies the demographic effects of reduced economic growth and migration, offering a stark view of potential population trends. Below is an in-depth analysis of the findings and their implications.

In South Korea, the population distribution under the Normal Scenario peaks around 7.3 million (7.3×10^7), with a moderate spread between 7.0 million and 7.5 million. This suggests that under normal conditions, South Korea's population growth stabilizes but does not grow dramatically over 30 years. In contrast, the What-If Scenario shows the peak of the distribution shifting to approximately 6.0 million (6.0×10^7), with a range between 5.5 million and 6.5 million. The leftward shift is pronounced, indicating a significant reduction in population growth when economic and immigration rates are halved.

South Korea's population is already vulnerable due to its low fertility rate and rapidly aging population. Over 30 years, the What-If Scenario demonstrates a stark decline in population compared to the Normal Scenario, with a difference of over 1.3 million people at the peak. This decline reflects the combined impact of reduced immigration and slower economic growth, which exacerbate existing demographic challenges. The narrower spread of the orange histogram indicates a reduced level of uncertainty in the projections under the What-If conditions, suggesting that the population decline is a more predictable outcome when growth and migration rates are curtailed. Without significant intervention, South Korea will likely face labor shortages, increased dependency ratios, and economic stagnation.

For Singapore, the Normal Scenario projects a population distribution that peaks around 12.0 million (1.2×10^7), with a range between 11.5 million and 12.5 million. This suggests strong and sustained population growth under normal economic and migration conditions. However, in the What-If Scenario, the peak shifts to approximately 8.0 million (8.0×10^6), with a range between 7.5 million and 8.5 million. The leftward shift is dramatic, indicating a substantial reduction in population growth when economic and migration rates are halved.

Singapore's population growth is highly dependent on immigration, given its consistently low fertility rates and limited natural population growth [22]. Over a 30-year horizon, the impact of reduced immigration becomes even more pronounced. The difference of 4 million people between the peaks of the Normal and What-If Scenarios underscores Singapore's reliance on foreign talent and workers to sustain its economic and population growth. The orange histogram for the What-If Scenario shows a tighter distribution compared to the blue histogram, reflecting reduced uncertainty in the event of slowed growth and reduced immigration. This pattern suggests a predictable and steady decline in population growth under adverse conditions, which could have far-reaching consequences for Singapore's status as a global financial hub, as a smaller population would directly affect workforce availability, innovation, and economic sustainability.

In Hong Kong, the Normal Scenario projects a population distribution that peaks around 13.0 million (1.3×10^7), with a range between 12.5 million and 13.5 million. The spread is relatively narrow, suggesting stable population growth under normal conditions. However, the What-If Scenario shows the peak shifting to approximately 9.0 million (9.0×10^6), with a range between 8.0 million and 10.0 million. This represents a significant leftward shift, indicating a sharp decline in population growth under reduced GDP and immigration rates.

Like Singapore, Hong Kong is heavily reliant on immigration to sustain its population and workforce. Over 30 years, the What-If Scenario highlights how reduced immigration and slower economic growth could lead to a population decline of nearly 4 million people compared to the Normal Scenario. The orange histogram demonstrates a slightly wider spread than those for South Korea and Singapore, indicating a higher degree of uncertainty in Hong Kong's population projections under adverse conditions. This uncertainty could arise from political and economic factors unique to Hong Kong, such as housing shortages, emigration of skilled workers, and geopolitical instability. A smaller population would exacerbate existing challenges, including labor shortages, reduced consumer demand, and a potential decline in Hong Kong's competitiveness as an economic hub.

Across all three regions, the What-If Scenario histograms show significant leftward shifts compared to the Normal Scenarios. This reflects the profound impact of reduced GDP growth and immigration rates on long-term population dynamics. The magnitude of the shift is particularly pronounced for Singapore and Hong Kong, indicating their greater reliance on immigration.

In terms of population decline, South Korea experiences a more moderate reduction in absolute terms, but this trend is troubling given the region's already low fertility rate and aging population. In contrast, Singapore and Hong Kong face much larger declines, with reductions of 4 million people over 30 years. Such dramatic changes would have severe implications for their economies, infrastructure, and global competitiveness.

The orange histograms generally exhibit narrower spreads than their blue counterparts, indicating that the outcomes under the What-If Scenario are more predictable. However, this predictability comes with the certainty of negative outcomes, including population stagnation or decline.

To address these challenges, policymakers must focus on several key areas. For Singapore and Hong Kong, maintaining high immigration rates is crucial to sustaining their populations and economies. Relaxing immigration restrictions and incentivizing skilled workers to migrate could mitigate the effects of reduced natural growth [22].

South Korea, traditionally less reliant on immigration, will need to adopt more proactive immigration policies to offset its aging population and declining birth rates.

Additionally, policies that stimulate GDP growth, such as investing in technology, education, and innovation, are critical to making these regions attractive to immigrants and ensuring long-term economic sustainability [23]. Governments must also address structural challenges, such as housing affordability in Hong Kong and Singapore, to remain competitive as destinations for foreign workers.

In South Korea, aggressive policies to encourage higher fertility rates, such as offering financial incentives, subsidizing childcare, and providing parental leave benefits, are essential. Singapore and Hong Kong could also explore measures to support families and improve work-life balance to boost natural population growth.

Long-term planning is essential as well. Governments need to prepare for potential labor shortages by investing in automation and artificial intelligence to maintain productivity with smaller populations. Infrastructure and social services must adapt to accommodate changing demographic profiles, including aging populations and reduced workforce participation [15].

The 30-year projections highlight the profound demographic and economic consequences of reduced GDP growth and immigration rates for South Korea, Singapore, and Hong Kong. The leftward shifts in the histograms underscore the vulnerability of these regions to adverse population trends, particularly in the absence of robust immigration policies and economic growth. Policymakers must act decisively to address these challenges, leveraging immigration, innovation, and family support policies to ensure sustainable population growth and economic stability in the decades to come. Failure to do so could result in stagnation, diminished competitiveness, and significant social and economic strain.

V. CONCLUSION

The comprehensive analysis presented in this report lays bare the intricate demographic dynamics faced by the Four Asian Tigers - Hong Kong, Singapore, South Korea, and Taiwan. These once-thriving economic powerhouses now find themselves at a critical juncture, grappling with the far-reaching implications of population shifts that threaten to disrupt their continued prosperity.

At the heart of the matter is the delicate balance between population growth, urban planning, and economic health - a triumvirate that has long underpinned the success of these regional giants. The sensitivity analyses and advanced modeling techniques employed in this study reveal the complex interdependencies at play, underscoring the pressing need for policymakers to adopt a holistic, multifaceted approach to address demographic challenges.

Hong Kong's steep population growth sensitivity highlights the vulnerabilities inherent in densely populated city-states, where even minor fluctuations in birth rates can have outsized impacts on infrastructure, resource allocation, and economic stability. In contrast, Singapore's more nuanced approach to immigration has allowed it to maintain a steadier population trajectory, offering valuable lessons for its neighbors facing more pronounced demographic shifts.

Meanwhile, South Korea and Taiwan's diverging paths which are the former's relative insensitivity to birth rate changes, and the latter's more precarious dependency illuminate the diverse set of considerations that shape each country's demographic landscape. These distinctions demand tailored policy responses, from pronatalist initiatives to workforce development strategies, to ensure the long-term sustainability of their social welfare systems and economic vitality.

Underpinning these regional variations is the fundamental recognition that population dynamics and economic health are inextricably linked. As the report's findings suggest, the historical model of growth-driven population increase must now give way to a more holistic, future-oriented approach. Also, compares persistence across a wider range of geographic factors, and investigate relative position within networks, and general network effects, at a range of scales [24]. Policymakers must prioritize measures that encourage higher birth rates, optimize immigration flows, and address environmental concerns – all while maintaining a keen eye on the implications for urban planning, resource allocation, and labor market dynamics.

To navigate this demographic crossroads successfully, the Four Asian Tigers must harness the power of data-driven decision-making. The integration of AI and advanced analytics into urban planning and construction management can enhance the precision and effectiveness of interventions, ensuring that investments in infrastructure and public services align seamlessly with evolving population needs.

Ultimately, the lessons from this report underscore the imperative for policymakers in the Four Asian Tigers to adopt a multifaceted, proactive approach. By aligning urban planning, economic development, and social policies, these regions can chart a course towards a future of sustainable growth, resilient urban environments, and equitable prosperity. The challenges they face may be daunting, but the rewards of successful navigation extend far beyond their own borders, serving as a beacon for other rapidly urbanizing regions worldwide.

VI. FUTURE WORK

Future research on the integration of AI techniques using Python for modeling population growth in construction engineering, particularly in the context of the Asian Tigers—Hong Kong, Singapore, South Korea, and Taiwan—could delve into several promising areas. To begin with, broadening the analysis to encompass additional demographic factors, such as age distribution, might offer a more detailed understanding of population dynamics. Utilizing machine learning algorithms like ensemble methods or neural networks could improve the accuracy of predictions and uncover complex patterns within the dataset. Beyond the Four Asian Tigers, this methodology could be applied to other rapidly urbanizing regions, especially in developing economies, to assess the adaptability of AI models in various contexts. Expanding the framework to include global datasets and conducting regional comparisons would additionally help validate the efficacy of the models. Also, it can aim to gauge the impact of AI on the economy, specifically on long-run economic growth [25]. The prospect of real-time population tracking is an exciting opportunity, leveraging streaming data from sources such as social media and mobile networks to provide immediate insights for construction planning and urban management.

Future research should also address ethical and policy considerations, ensuring that AI models are transparent, unbiased, and compliant with data privacy regulations. Developing frameworks to integrate AI-driven forecasts into government strategies and construction policies will be vital for maximizing their real-world impact. Combining AI techniques with traditional statistical and demographic-economic models could result in a more thorough understanding of population growth dynamics. For example, blending machine learning with agent-based modeling could replicate behaviors that influence population trends, while conducting AI-supported sensitivity analyses could reveal how variations in key parameters affect outcomes. Furthermore, creating user-friendly Python-based visualization tools, such as interactive dashboards and decision support systems, would enable policymakers and engineers to analyze trends and simulate "what-if" scenarios. Interdisciplinary collaboration involving experts in urban planning, sociology, climate science, and economics would enhance the contextual relevance and accuracy of AI models. Developing open-source Python frameworks for population growth modeling represents a promising direction, as it would allow researchers and practitioners to contribute to and benefit from collective advancements. Validation through longitudinal studies that compare AI predictions with actual outcomes over extended periods will also be crucial for improving model reliability and credibility. By exploring these pathways, the methodologies for incorporating AI in population growth modeling can be further enhanced, providing actionable insights for construction engineering and urban planning, not only in the Four Asian Tigers but also in other rapidly expanding regions globally.

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VIII. APPENDIX

Contribution Table

Student ID/ Name	Description of Contribution	Percentage of Contribution	Student Sign
24108427D / Liora Lyn Theadora	III. A. Simulation Results III. B. Performance Analysis and Metrics III. C. Comparative Graph and Comparative Analysis IV. A. Sensitivity Analysis IV. B. Economic Influences & Policy Implications VII. References Citation	20%	
24116391D / Enzo Orlando Taslim	Impact Statement III. B. Performance Analysis and Metrics (metrics codes) IV. B. Economic Influences & Policy Implications IV. C. Environmental Factors IV. D. Stochastic Modeling Using Monte Carlo Simulations IV. E. Impact of Immigration (codes) IV. G. What-If Scenario V. Conclusion Extra codes: R2 MSE MAE graph	20%	
24104787D / Yong Cai Xuan	I. Introduction III. F. Time Series Analysis IV. E. Impact of Immigration(Explanation) Video Editing Citation	20%	
24114054D / Gandhi Prema Perwira	Abstract VI. Future Work Citation	20%	
24100401D / Febryano Hizkia Detesta	II. Statistics A. Concepts B. Models C. Flowchart & Algorithm Latex coding for mathematical formulas interpretation	20%	