Economic - Environmental Determinants of Quality of Life: A Predictive Analytics Approach for Sustainable Development

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Abstract

In this project we will take a look at economic output and environmental indicators. Specifically looking at the indicators for renewable energy to see if these play a massive role in country and human development. From there we will look into if these indicators will contribute to what this research will consider as ‘high quality of life’. This research will determine the high quality of life and the impacts of these factors. The database will take five different countries and take a look at different aspects of indicators including adoptions and economic spending of renewable energy and its impacts on development of countries. The data will then use python to determine different correlations between these indicators. With the conclusion showing how some developing countries have higher renewable energy output with a lower quality of life along with USA meeting lower than expected is most metrics

Introduction

Problem statement:

This project explores how economic, social, environmental, statistical indicators use impact quality of life across five countries. Using Python, we apply both predictive and explanatory methods to study these relationships. Some countries show high renewable output but low quality of life. Our goal is to understand and predict these patterns to support better development strategies.

01 Analyze the relationship between economic performance indicators and human development outcomes across five economies.

02 Quantify the links between carbon intensity, renewable energy adoption, and resource utilization across development stages

03 Predict and classify a country's quality of life based on economic, environmental, and social indicators.

Research Questions

1

How have changes in GDP influenced life expectancy and poverty indicators over the past three years, and what temporal lags exist between economic investments and measurable human development outcomes?

2

How do import trends in ICT, capital, consumer, and intermediate goods reflect the technological strategies and GVC roles of the economies 2021–2023)?

3

To what extent can future renewable energy adoption rates be predicted using historical data on FDI flows, international trade patterns, and government expenditure on environmental initiatives?

4

What combination of environmental indicators and economic metrics most accurately classifies a country's sustainability performance?

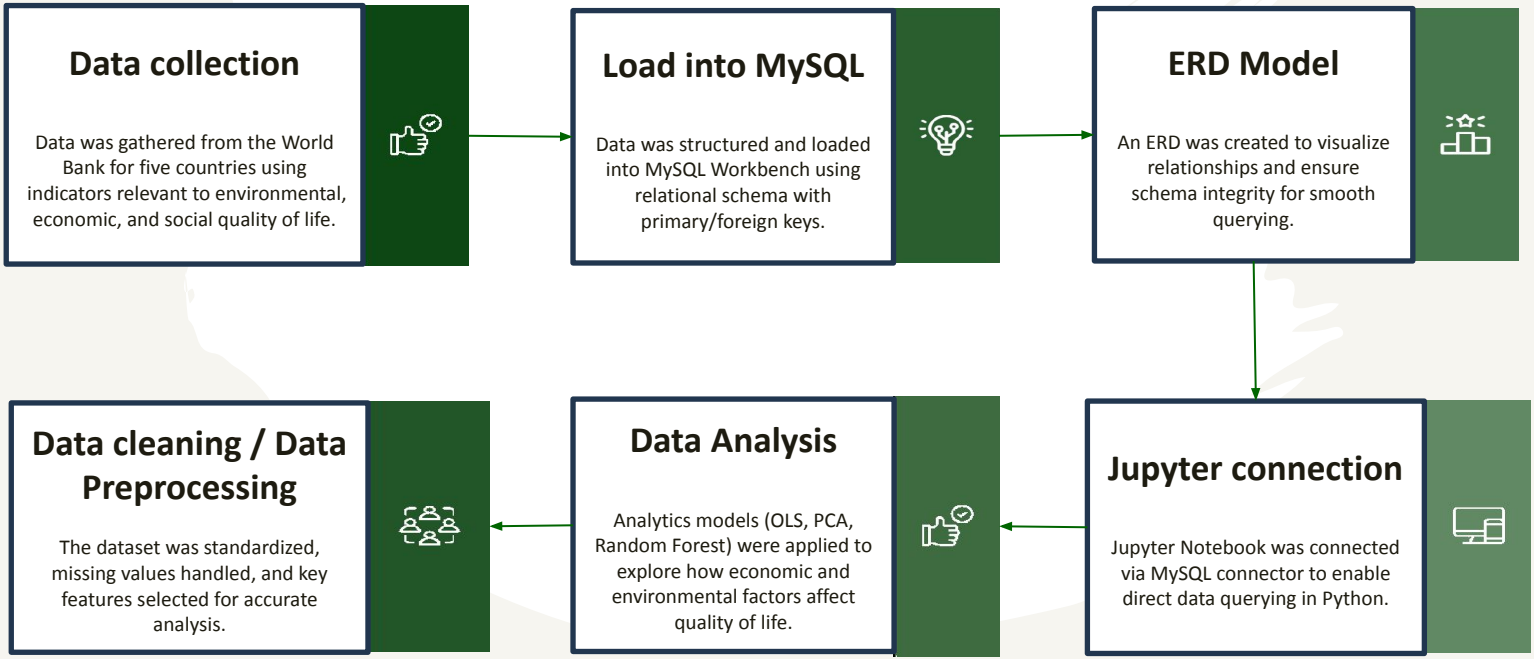
5

How should the country be ‘high quality’ and how should this be labeled? Should Logistics Regression be used? Should any other classification model be used?

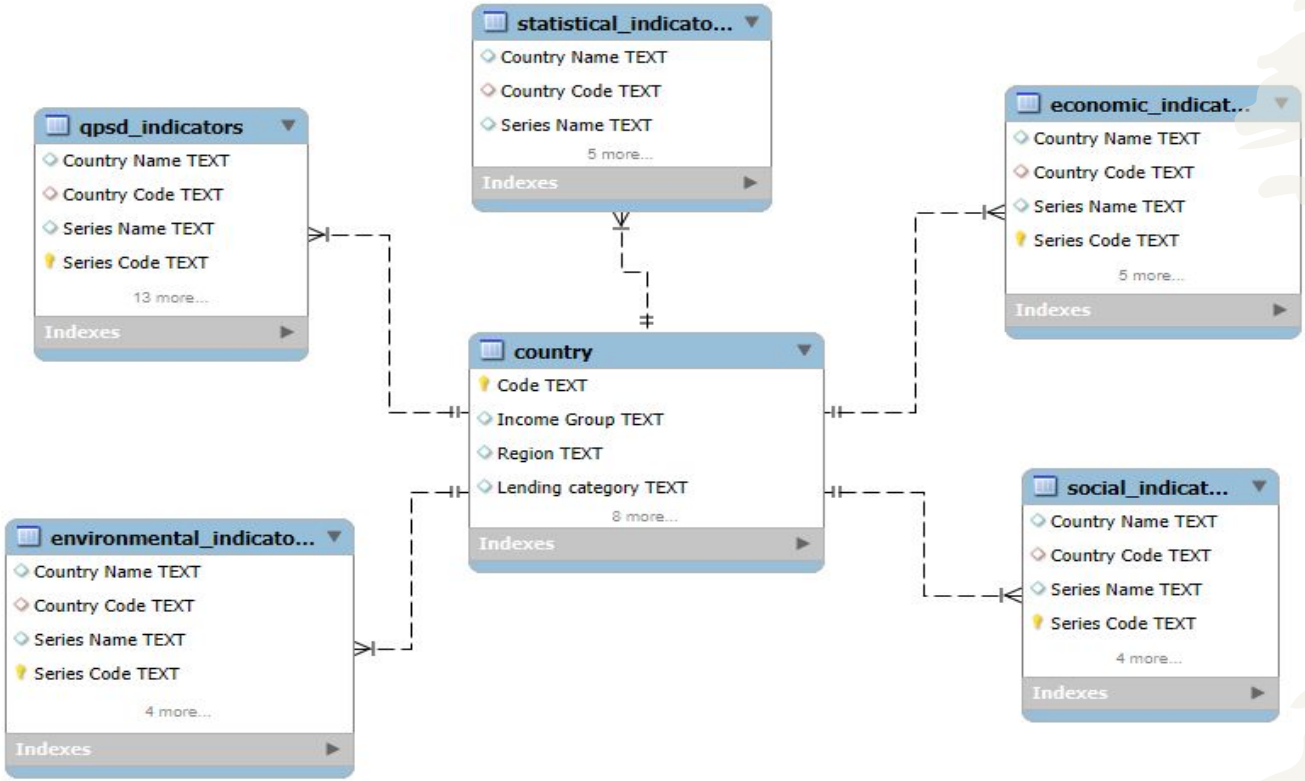
6

Which features most influence quality of life, and do environmental factors vary significantly across countries in ways that affect it?

Data Pipeline Overview



ERD Model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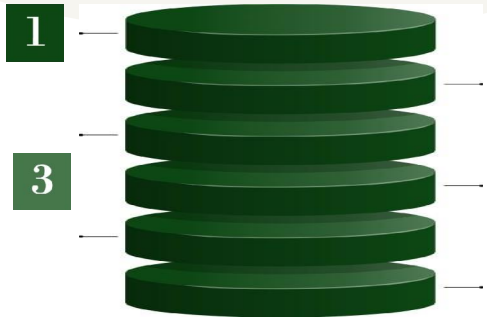
GDP Changes and Life Expectancy - Lag Analysis

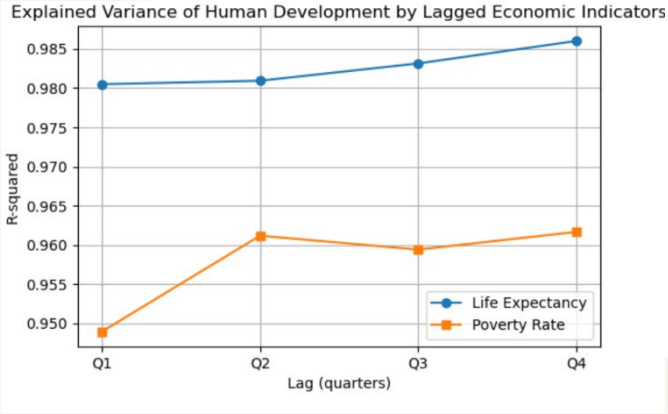
Lag analysis showed that GDP impacts are strongest after 4 quarters, improving both life expectancy (R^2 = 0.986) and reducing poverty (R^2 = 0.962).

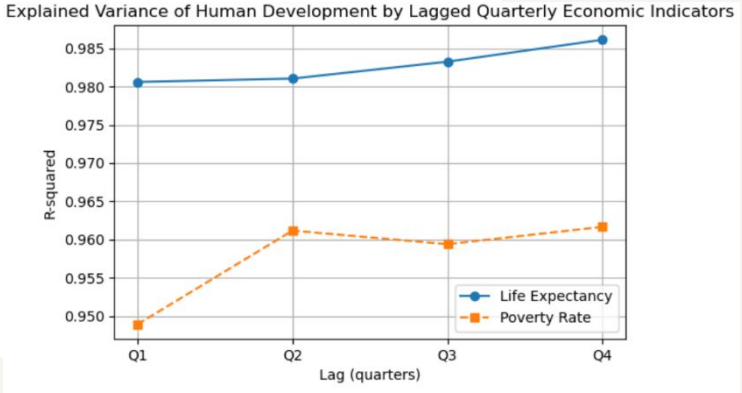
Life expectancy responds more gradually to GDP changes, whereas poverty shows quicker reactions.



FDI had minimal short-term impact, suggesting policy focus should be on long-term investment planning.

Sustained GDP growth is a primary driver of human development outcomes across all five countries.

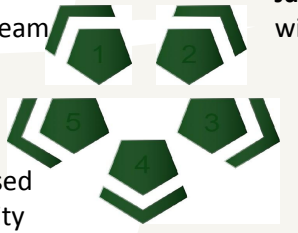




ICT Import - Cluster Analysis

USA, Germany, China: Import intermediate inputs; act as downstream hubs with high backward GVC integration.

India: Imports capital goods; focused on industrial upgrading and capacity building.



Japan: Imports ICT goods; upstream role with strong forward GVC participation.

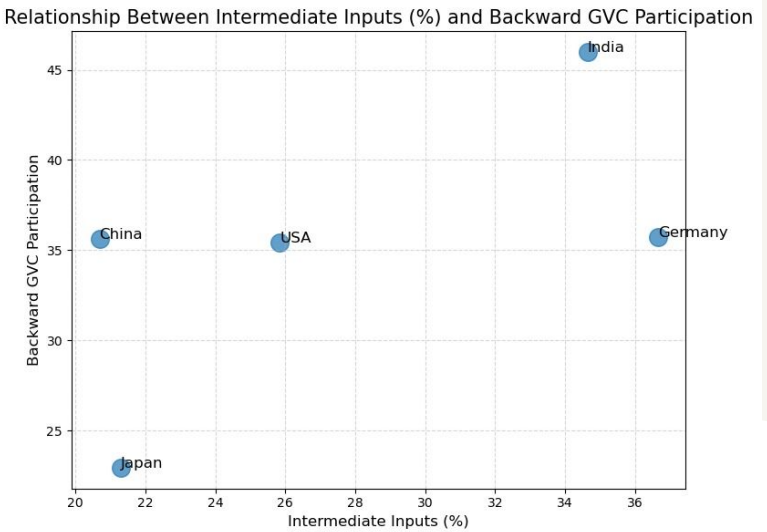
India: High domestic value addition despite mixed GVC orientation.

Country clusters:

India = Emerging economy focused on industrial upgrading

Japan = Advanced upstream economy with strong technology exports

USA / Germany / China = Advanced downstream economies with complex value chains

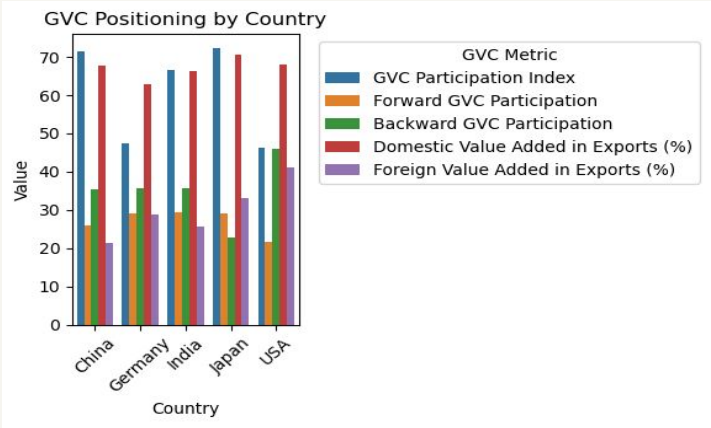


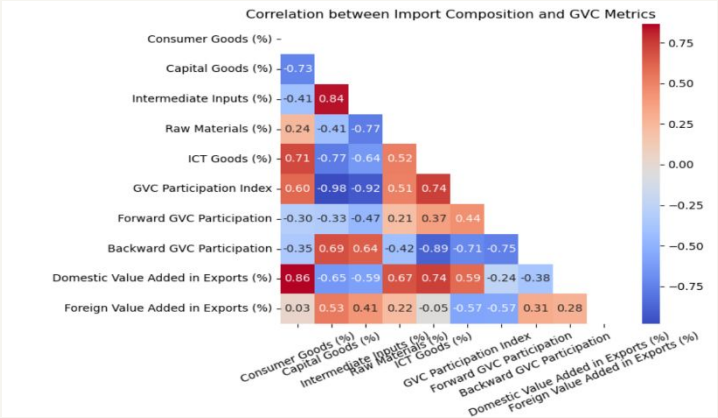
- USA, Germany, and China mainly import intermediate inputs and act as downstream GVC hubs.
- Japan imports more ICT goods and plays an upstream role with high forward GVC participation.
- India focuses on capital goods for industrial upgrading, showing high domestic value-added.
- Most countries are domestic value-added dominant, reflecting strong internal production.
- PCA clustering forms two groups:

  Cluster 0: USA, Germany (balanced roles)

  Cluster 1: India, China, Japan (diverse GVC roles)

- Intermediate inputs correlate positively with GVC participation; capital goods show a negative link with forward GVC roles.

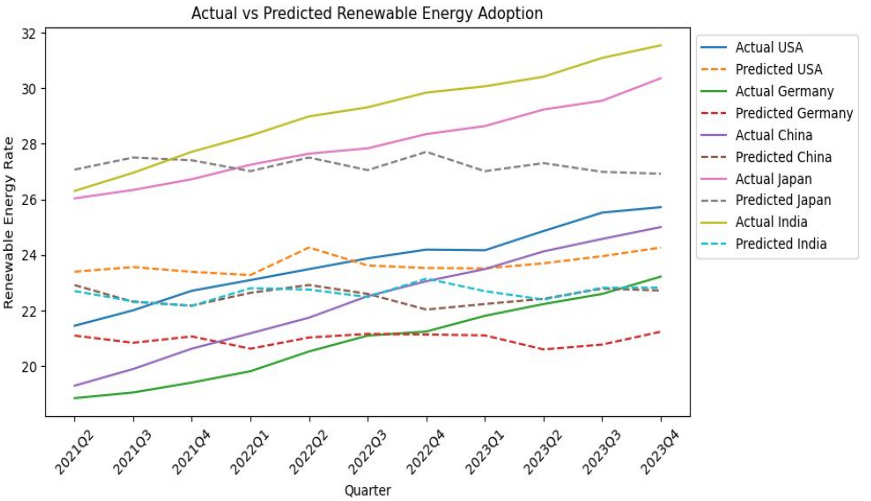




Renewable Energy Predictive Analysis Using Bayesian Bridge

- Prediction model showed high accuracy, with **China having the fastest** growth and **India the slowest.**
- Government spending was the most influential predictor, outperforming trade and FDI.
- Short-term trends are predictable; long-term shifts require policy modeling.

Investment in green policy accelerates renewable adoption more effectively than trade or FDI.



Classification of Countries based on Sustainability Performance using Random Forest

- A **Logistic Regression** using just 3 environmental indicators (CO_2, renewable %, forest area) achieved **93% accuracy.**

- Economic metrics like GDP and imports were not strong sustainability predictors.

- Environmental metrics are more robust classifiers than traditional economic measures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=== Best Model ===
Best model: Environmental Only - Logistic Regression
Accuracy: 0.9333
Features: ['co2_emissions_per_capita', 'renewable_energy_pct', 'forest_area']
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High Quality Countries Using Correlation Analysis

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Comparison of Rankings (Environmental Score vs. Total Quality Score):
USA: Environmental Rank: 3, Total Rank: 2, Difference: 1
Germany: Environmental Rank: 4, Total Rank: 4, Difference: 0
China: Environmental Rank: 2, Total Rank: 1, Difference: 1
Japan: Environmental Rank: 1, Total Rank: 3, Difference: -2
India: Environmental Rank: 5, Total Rank: 5, Difference: 0
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Countries Ranked by Environmental Score:
1. Japan: 25.62 (Quality: Standard Quality)
2. China: 23.20 (Quality: High Quality)
3. USA: 21.51 (Quality: High Quality)
4. Germany: 20.36 (Quality: Standard Quality)
5. India: 18.25 (Quality: Standard Quality)
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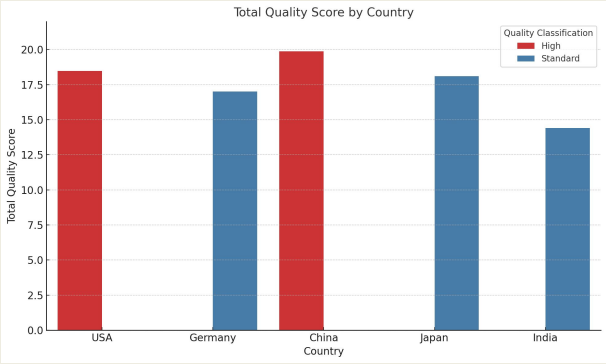


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Environmental Factors with Greatest Variation Across Countries:
pollution_deaths_per_100k: 52.32
renewable_energy_percentage: 27.40
environmental_performance_index: 25.64
waste_management_score: 23.01
air_quality_index: 21.55
climate_vulnerability_index: 14.69
water_quality_index: 14.19
access_to_green_spaces: 12.32
forest_cover_percentage: 12.26
protected_land_percentage: 8.05
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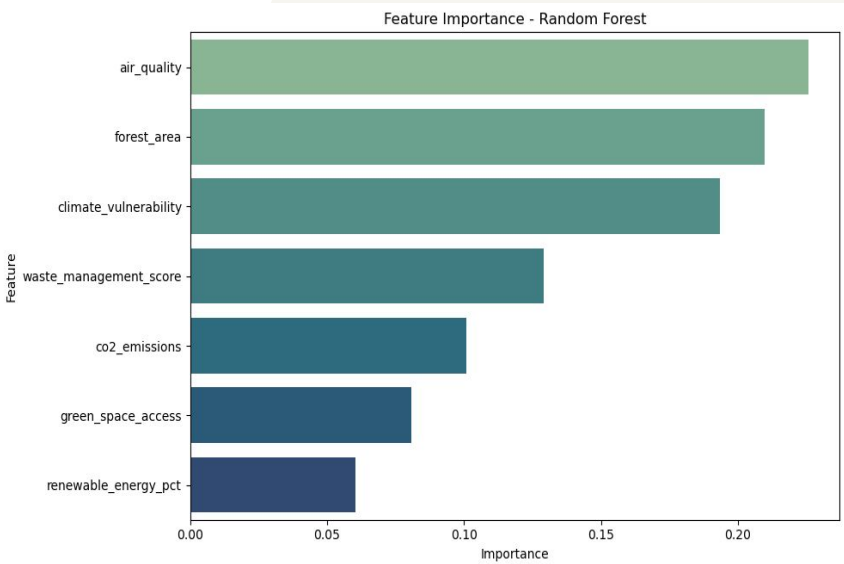
Environmental Determinants of Quality of Life Across Countries

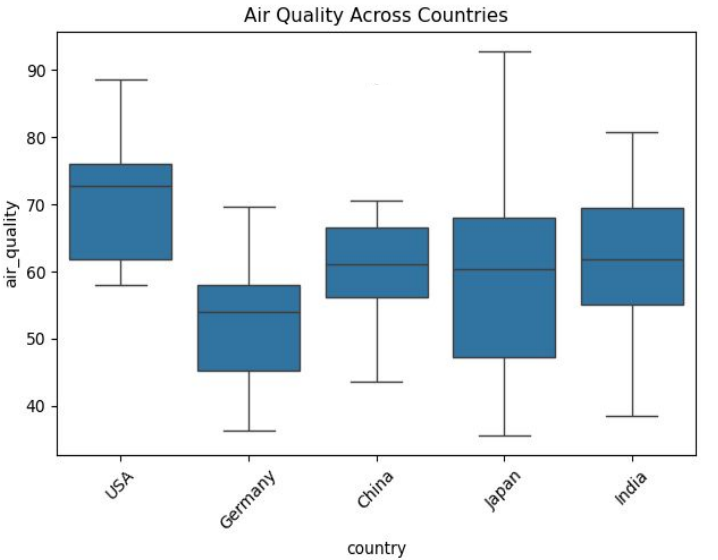


- Air quality emerged as the most influential factor in determining quality of life across countries.
- Other key drivers include forest area, climate vulnerability, and waste management.
- Renewable energy had the lowest predictive power in the model.
- The model achieved moderate classification performance, suggesting environmental variables alone can partially explain high quality of life.
- These findings support integrating environmental policies into broader development frameworks.

- p = 0.0199 air quality showed a statistically significant difference between high and low quality-of-life countries.
- Other factors like CO_2 emissions and green space access were not significantly different ($p > 0.1$).

- p = 0.0544 ANOVA test for air quality across countries showed variation, just above the conventional significance threshold.
- **USA and Japan** displayed higher median air quality compared to others, with **Germany having the lowest**.

These insights highlight the critical role of clean air in defining life quality, justifying stronger environmental regulation in policy planning.



Conclusion

- While GDP rises, food systems and rural livelihoods may face strain unless sustainable land-use planning is implemented.
- Investing in renewables strengthens environmental performance, reduces health risks, and supports long-term, low-carbon economic growth.
- Loss of forests contributes to poor air quality, weaker climate resilience, and overall environmental degradation.
- Social indicators (literacy, poverty, life expectancy) are vital to long-term success.

Ultimately, this study underscores that true sustainability lies at the intersection of economic prosperity, environmental integrity, and responsible land management—a balance essential for shaping resilient, future-ready nations.

Insights for Policy Makers

Lagged GDP growth

Boosts life expectancy and reduces poverty.

Renewable adoption

Most influenced by government spending.

ICT imports

Drive tech growth and GVC integration.

Air quality and pollution deaths

Shape life quality outcomes.

GVC roles

Vary—policy should match each country's trade position.

Sustainability scoring

Helps track and guide national development.

Limitations / Future work

Study scope is limited to 5 countries over 3 years; expanding coverage will enhance generalizability

Findings are correlational; causal inference requires structural or longitudinal modeling approaches.

Environmental indicators lacked spatial granularity; incorporating regional data (e.g., urban vs. rural) is recommended.

Inclusion of simulated variables may reduce real-world applicability; future work should prioritize validated datasets.

Model performance was moderate; ensemble or deep learning models may yield higher predictive accuracy.

Future research should integrate additional socioeconomic and climate-related variables to enrich quality-of-life modeling.

Resources & References

https://databank.worldbank.org/databases/page/1?qterm=global

https://www.mdpi.com/2071-1050/15/13/10682

Thank you