



Drivers Of Bilateral Renewable Energy Trade: Evidence From India–Uae Relations

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Abstract: This study explores the bilateral trade dynamics in renewable energy between India and the United Arab Emirates (UAE), focusing on its role in achieving the Sustainable Development Goals (SDGs), particularly clean energy access and climate action. Both countries have made significant progress in renewable energy, driven by supportive policies, technological advancements, and global sustainability commitments. This research investigates the key factors influencing renewable energy trade, including economic growth, renewable energy capacity, trade facilitation measures, and international agreements that shape bilateral trade flows.

The period from 2019 to 2024 has seen significant global disruptions, policy shifts, and technological innovations, impacting trade relations. This study utilizes econometric analysis to assess the relationship between the aforementioned variables and renewable energy trade between India and the UAE. The findings provide valuable insights for policymakers and industry stakeholders to strengthen renewable energy cooperation, promote technological innovation, and support the transition to sustainable energy, aligning with India's Vision Viksit Bharat@2047.

Keywords: Bilateral trade, renewable energy, India-UAE relations, Sustainable Development Goals, Viksit Bharat@2047, policy shifts.

I. INTRODUCTION

This study examines the multifaceted dynamics influencing bilateral renewable energy trade between India and the United Arab Emirates (UAE), emphasizing the roles of logistics performance, economic growth, renewable energy capacity, international agreements, and policy initiatives. As global momentum toward sustainable energy accelerates, understanding the drivers that enhance renewable energy trade between these two key energy actors is vital for strategizing policy, investment, and international collaboration.

India, as the world's third-largest energy consumer, faces rising energy demand amid its rapid economic growth and urbanization. Despite significant investments in renewable energy aiming for 500 GW of non-fossil capacity by 2030 the country still grapples with energy security challenges, intermittent renewable sources, and a dependence on fossil fuels. Concurrently, the UAE has emerged as a strategic partner, leveraging its investments and expertise in renewable energy and nuclear technologies to support India's sustainability goals. Bilateral initiatives such as the India-UAE strategic partnership, joint development of clean energy projects, and the India-Middle East-Europe Economic Corridor (IMEEC) exemplify concerted efforts to promote sustainable energy cooperation.

This research explores how key factors namely logistics performance, economic growth, renewable energy indicators, and international agreements drive renewable energy trade between India and the UAE. The analysis employs a comprehensive econometric approach, utilizing pooled regression, principal component analysis (PCA), Lasso models, and descriptive statistics, to identify the significance and interactions of these variables over the period 2019–2024, a timeframe marked by global policy shifts, technological advancements, and pandemic-induced disruptions.

The findings reveal that economic growth (GDP) and logistics performance are the primary determinants of increasing renewable energy trade flows. Robust economic expansion boosts energy demand and fosters investment in renewable infrastructure, while efficient logistics systems facilitate the smooth transfer of equipment, technology, and energy resources, reducing costs and improving trade efficiency. Conversely, while renewable energy indicators (RE) and international agreements (IA) play secondary roles, they nonetheless contribute to the broader ecosystem that sustains bilateral trade. Investments in renewable capacity and adherence to international protocols create a favourable environment for trade expansion.

Policy analysis underscores the importance of strategic investments in logistics infrastructure ports, transportation networks, and storage facilities to streamline trade. Harmonization of standards, facilitation of customs procedures, and bilateral research exchanges are crucial to eliminate barriers. Additionally, fostering domestic renewable capacity through supportive regulatory frameworks, tax incentives, and targeted subsidies amplifies trade prospects. Strengthening international agreements, such as MoUs and joint declarations, reinforces mutual commitments, aligns regulatory standards, and encourages technology sharing.

Technological innovation emerges as a catalyst, enhancing the efficiency and competitiveness of renewable energy technologies. Collaborations on R&D, deployment of smart grid systems, and adoption of digital solutions for energy management are pivotal to advancing bilateral trade. The UAE's investments in solar PV

and nuclear energy, complemented by India's expansive renewable targets, exemplify how innovation accelerates shared objectives for sustainability and energy security.

In conclusion, the study delineates a clear pathway for policymakers and industry stakeholders to bolster renewable energy trade between India and the UAE. Prioritizing logistics infrastructure, fostering sustainable economic growth, cultivating international cooperation, and encouraging technological innovation are foundational to this endeavour. These strategies not only support bilateral energy security but also contribute substantially to global climate commitments and sustainable development goals. Future research should focus on the interaction effects among these drivers and explore long-term impacts, incorporating broader datasets and extended periods to refine strategic frameworks. This integrated approach will be critical in advancing efficient and resilient renewable energy markets in a rapidly changing global landscape.

Introduction

The move to renewable energy is critical for combating climate change, reducing environmental damage, and supporting long-term energy solutions (Fen et al., 2024). Renewable energy, which comes from naturally replenishing sources such as solar, wind, hydropower, geothermal, and biomass, is a greener alternative to fossil fuels. These systems emit significantly less greenhouse gases, making them critical for addressing climate-related concerns (Lahiri, 2024).

India, the third-largest consumer of energy globally, faces an ever-increasing demand for energy due to its growing population and rapidly expanding economy. In 2023, India's peak energy demand reached a record 223 gigawatts (GW), a 3.4% increase from the previous year (International Trade Administration, 2024). The country's energy sector is diverse, with a mix of fossil fuels and renewable sources, including solar, wind, and biomass. Despite this diversity, fossil fuels continue to dominate India's power sector, though the government has set ambitious renewable energy targets to reduce reliance on non-renewable sources. By 2030, India aims to achieve 500 GW of non-fossil energy capacity and fulfil 50% of its energy requirements through renewable energy.

As of May 2023, India's installed renewable energy capacity reached 179 GW, primarily derived from solar (67 GW) and wind (43 GW), with the remainder from small hydro and biomass. However, the gap between installed capacity and actual production is due to the intermittent nature of some renewable sources, particularly solar and wind. India's commitment to expanding its renewable energy sector aligns with global sustainability goals and its pledge to achieve net-zero emissions by 2070 (Genspark, 2024).

On the international front, India has been actively strengthening its energy ties with the United Arab Emirates (UAE), particularly in the renewable energy sector. According to *The Economic Times* (2024), in December 2024, the two countries discussed the implementation of the India-Middle East-Europe Economic Corridor (IMEEC), focusing on long-term energy supplies, renewable energy collaboration, and joint development of clean energy technologies. This bilateral engagement underscores the shared vision of India and the UAE in advancing sustainable energy solutions. This growing collaboration in clean energy, particularly in renewable

energy technologies and infrastructure, provides a fertile ground for examining the factors that drive bilateral trade in this sector. Understanding these dynamics is essential to developing strategies that can further enhance the trade relationship between India and the UAE. The study explores how logistics performance (LPI), economic growth (GDP), renewable energy indicators (RE), and international agreements (IA) influence trade volumes.

Renewable energy was a central topic during the 15th India-UAE Joint Commission Meeting (JCM), where foreign ministers from both nations deliberated on expanding their strategic partnership. The discussions spanned various critical sectors, including defence, emerging technologies, nuclear energy, polar research, and renewable energy (FE Business, 2024). The ministers underscored the importance of deepening cooperation in the renewable energy sector, which is integral to both countries' efforts to transition towards cleaner and more sustainable energy sources.

Additionally, in September 2024, India and the UAE signed a Memorandum of Understanding (MoU) between the Emirates Nuclear Energy Corporation (ENEC) and the Nuclear Power Corporation of India Limited (NPCIL) to cooperate on the operation and maintenance of the Barakah Nuclear Power Plant in the UAE (Joshi & Gupta, 2024). While nuclear energy is a key focus of this collaboration, the emphasis on renewable energy remains central to both countries' broader energy strategies.

The UAE, a prominent investor in energy sectors, plays a pivotal role in bolstering India's renewable energy objectives. Through ongoing agreements and joint initiatives, the two nations are fostering innovation in clean energy technologies while addressing global sustainability challenges. This paper delves into the intricacies of bilateral renewable energy trade between India and the UAE, exploring the critical role of logistics, economic growth, and international agreements in shaping this collaboration.

In this context, the growing energy cooperation between India and the United Arab Emirates (UAE) plays a significant role in strengthening the bilateral renewable energy trade. The two countries have been actively working together on long-term energy supplies and renewable energy collaboration, including joint development of clean energy technologies. According to The Economic Times (2024), in December 2024, the two nations discussed the implementation of the India-Middle East-Europe Economic Corridor (IMEEC), which aims to enhance energy security, infrastructure connectivity, and sustainability. This bilateral engagement underscores the shared vision of India and the UAE to promote renewable energy solutions.

The central aim of this paper is to explore the dynamics of bilateral renewable energy trade between India and the UAE, specifically focusing on the factors that drive trade. The study examines the roles of logistics performance (LPI), economic growth (GDP), renewable energy indicators (RE), and international agreements (IA) in influencing trade volume. The hypothesis posits that improved logistics performance and economic growth will significantly enhance bilateral renewable energy trade, while renewable energy indicators and international agreements will play a secondary role. This paper hypothesizes that both logistics performance and economic growth (GDP) are key drivers of bilateral renewable energy trade between India and the UAE.

In contrast, renewable energy indicators (RE) and international agreements (IA) are expected to have a secondary, though still relevant, role in influencing trade volumes.

This study aims to analyse the dynamics of bilateral renewable energy trade between India and the UAE, with a focus on understanding the key drivers influencing trade volume. Specifically, the paper seeks to:

1. Examine the impact of logistics performance (LPI), renewable energy indicators (RE), and economic growth (GDP) on trade volume between India and the UAE.
2. Assess the role of renewable energy investments and usage (RE) in fostering bilateral trade, and how these factors contribute to enhancing trade flow.
3. Evaluate the influence of international agreements (IA) in facilitating or constraining renewable energy trade, considering their potential role in strengthening bilateral ties and trade dynamics.
4. Analyse the overall relationship between logistics performance, renewable energy, economic growth, and trade, providing a comprehensive understanding of the interactions at play.

The subsequent sections of this paper will review the relevant literature, outline the research methodology and data sources, present the results from the pooled regression, Descriptive Statistic, Principal Component Analysis (PCA) and Lasso models, and conclude with policy recommendations to strengthen India-UAE renewable energy trade.

Review of Literature

India's growing energy demand and the UAE's significant role as an energy exporter have redefined their bilateral relationship. Pradhan (2008) emphasizes how the global energy regime has influenced India's engagement with the Gulf Cooperation Council (GCC), particularly the UAE. Over time, renewable energy has emerged as a cornerstone of this partnership, critical to India's transition toward sustainable energy. Pradhan highlights the interdependence between India and the GCC, offering insights into the dynamics of energy cooperation and its role in shaping India's clean energy strategies. Fatima Anjum (2017) examines India's increasing strategic engagement with the UAE, focusing on areas such as defence, security, energy, and trade. She highlights agreements that strengthen bilateral ties, including those on counterterrorism, defence cooperation, and energy security. Anjum notes the growing maritime security and counter-extremism collaborations and the UAE's support for India's bid for permanent membership in a restructured United Nations Security Council. The alliance has extended beyond traditional areas of cooperation, addressing cybersecurity, renewable energy, and defence, with energy security remaining a key focus. Renewable energy sources (RES) have historically played a pivotal role in human development, with early use in hydropower, solar thermal, geothermal, and wind energy. However, the industrial era prioritized fossil fuels. The oil crises of the 1970s reignited interest in RES, prompting research and investments. Al-Amira and Abu-Hijleh (2013) note that modern renewable energy technologies gained traction during this period, driven by environmental concerns and the need to reduce fossil fuel dependency. Despite advancements in solar photovoltaics (PV)

and wind energy, barriers such as costs and inefficiency persist. The UAE, despite its abundant solar resources, faces challenges in policy-making and regulatory frameworks, which hinder the widespread adoption of RES.

Logistics has emerged as a vital sector, enhancing transport infrastructure and supporting economic growth. Effective logistics improves corporate efficiency and fosters national development by creating jobs, driving income, and facilitating trade. Górecka et al. (2021) emphasize the critical role logistics performance plays in energy trade, with key subcomponents like timeliness significantly influencing the export and import of energy products. Their findings highlight how logistics efficiency directly impacts trade integration and economic development. Gani's (2017) study underscores the importance of logistics infrastructure in international trade, linking logistics improvements to increased trade flows and economic growth. Similarly, Wan et al. (2022) explore logistics performance in the context of environmental sustainability, noting its correlation with CO2 emissions in emerging economies. They stress the need for clean energy adoption, efficient logistics, and green technologies to align logistics performance with sustainable development goals. In analyzing the determinants of bilateral renewable energy trade, addressing methodological challenges such as multicollinearity and overfitting is critical. Ranstan and Cook (2018) highlight Lasso (Least Absolute Shrinkage and Selection Operator) regression as a robust technique to mitigate these issues, particularly in high-dimensional datasets with limited observations. By penalizing regression coefficients, Lasso prioritizes variables with the most significant predictive power while reducing the risk of overfitting. This methodological approach has been instrumental in this study to isolate key predictors such as logistics performance, GDP, and renewable energy capacity—while ensuring the model's reliability and generalizability.

Kruckenbergh (2015) examines the role of inter-organizational relationships in renewable energy technology (RET) diffusion. The study finds that both strong and weak ties are necessary for RET success. While weak ties promote networking and inclusion, strong ties ensure trust, knowledge transfer, and project sustainability. Sustainable RET programs should balance these dynamics, fostering long-term partnerships and empowering local organizations for sectoral growth.

Methodology

This study adopts a dynamic and rigorous quantitative approach to unravel the key factors driving bilateral renewable energy trade between India and the UAE. By carefully analysing various economic and logistical indicators, the research aims to shed light on what truly influences trade volumes in this vital sector. To accomplish this, the study employs two complementary econometric techniques: pooled regression and Lasso regression.

The pooled regression provides a clear initial understanding of how different variables such as logistics performance, renewable energy capacity, economic growth, and international agreements interact to shape trade flow. Meanwhile, Lasso regression, a sophisticated regularization method, helps refine the analysis by effectively handling issues like multicollinearity (when variables are highly correlated) and overfitting (where the model becomes too tailored to specific data points).

Together, these methods allow for a comprehensive and robust identification of the most influential drivers, ensuring that the findings are both accurate and insightful. This combination not only enhances the reliability of the results but also offers a nuanced perspective on the complex dynamics influencing renewable energy trade between these two strategic partners.

Research Design and data collection

This study employs a quantitative methodological framework to examine the interrelationships between key determinants namely logistics performance, renewable energy indicators, economic growth, and international agreements and bilateral renewable energy trade between India and the UAE. The analysis begins with pooled regression to assess these associations comprehensively. To enhance model stability and address issues of multicollinearity, the study further incorporates Lasso regression, leveraging its regularization capabilities to refine variable selection. This dual analytical approach allows for a rigorous and nuanced exploration of the principal drivers underpinning trade dynamics, combining traditional statistical inference with advanced regularization techniques to ensure robustness and methodological rigor.

The data utilized in this study were sourced from credible international organizations, government reports, energy agencies, and relevant databases. The dataset spans five distinct periods 2019-2020, 2020-2021, 2021-2022, 2022-2023, and 2023-2024 enabling an examination of recent trends and short-term dynamics in renewable energy trade between the two countries.

Key variables collected include bilateral trade volumes of renewable energy, economic growth indicators (GDP), renewable energy capacity, logistics performance scores measured by the Logistics Performance Index (LPI), and information on international agreements (IA). The trade volume data specifically pertain to bilateral energy exchange, with GDP figures obtained from national statistical agencies and international economic databases. Logistics performance data, reflecting countries' infrastructure, customs efficiency, and transportation capabilities, were drawn from the LPI dataset. International agreements were recorded as binary indicators denoting the presence or absence of specific renewable energy treaties though some fluctuations over the years were observed.

Given the limited sample size of only five periods, Principal Component Analysis (PCA) was employed to address multicollinearity among highly correlated variables such as GDP, LPI, and renewable energy indicators. PCA effectively consolidates these variables into a single principal component (PC1), which captures over 97% of the variance, thus ensuring the robustness of subsequent regression analyses while reducing issues stemming from multicollinearity.

Through this careful data collection and processing integrating PCA and regression analysis the study establishes a solid foundation for identifying and understanding the key drivers of bilateral renewable energy trade, even within the constraints of a limited temporal dataset.

Given the focus on bilateral renewable energy trade between India and the UAE, the sampling method is focused on these two countries. The sampling is non-probabilistic, as the study specifically looks at the trade relationship between India and the UAE, excluding other countries from the analysis. The dataset includes yearly trade volumes, economic growth data, renewable energy capacity, logistics performance scores, and information on international agreements for the periods from 2019 to 2024.

Data Analysis

To address multicollinearity among GDP, LPI, and RE, Principal Component Analysis (PCA) was applied. PCA reduces dimensionality by summarizing correlated variables into principal components that capture most of the variance. The first principal component (PC1), explaining 97.67% of the variance, was selected as a composite index representing these predictors. This approach ensured the robustness of subsequent regression models by mitigating multicollinearity while retaining the core variance of these variables.

Regression Models

Two regression models, Pooled Ordinary Least Squares (OLS) and Lasso regression, were employed to analyse the relationship between trade volume and the key predictors (LPI, GDP, RE, and IA). PCA results informed the regression by replacing correlated variables with PC1, simplifying the model and improving interpretability. Lasso regression was used for its regularization capabilities to shrink insignificant variables, reducing overfitting and enhancing prediction reliability.

Justification for Using Lasso Regression

Lasso regression was chosen for this study due to its ability to address multicollinearity and overfitting, which are common issues when analysing a small dataset with multiple predictors. In the pooled regression model, high multicollinearity was observed between logistics performance (LPI), economic growth (GDP), and renewable energy indicators (RE), leading to inflated standard errors and difficulty in interpreting individual variable effects. Lasso regression adds a penalty term to the loss function, which shrinks the coefficients of less significant variables toward zero, thus mitigating the impact of multicollinearity.

Additionally, the small dataset (with only 10 observations) posed a risk of overfitting traditional regression models. Lasso's regularization ensures a more robust model by avoiding overfitting and focusing on the most important predictors. The use of Lasso regression also allowed for automatic variable selection, simplifying the model by retaining only the most significant predictors—GDP and LPI—while minimizing the influence of renewable energy indicators and international agreements. This approach enhances the interpretability of the results and provides actionable insights for policymakers.

Limitations

Several limitations need to be acknowledged in this study:

Sample Size: The dataset covers only 5 periods of data, due to unavailability of the data which limits the statistical power of the models. A longer time frame would have provided more robustness and allowed for the examination of long-term trends.

Country-Specific Factors: The study only focuses on India and the UAE, which limits generalizability. Other countries with different renewable energy strategies and economic conditions could show different results.

Linearity Assumption: Both models typically assume a linear relationship between the dependent and independent variables, which might not always capture more complex, non-linear relationships.

Results and Discussion

Descriptive Statistics

The descriptive statistics for the key variables in the analysis are presented in Table 1 below. The dataset covers the years 2019-2020 to 2023-2024, with data for both India and the UAE. Key variables include GDP, Logistics Performance Index (LPI), Renewable Energy (RE), International Agreements (IA), and Trade Volume (TV).

Table:1

Variable	Mean	Standard Dev	Minimum	Maximum
GDP(India)	12.487	0.035	12.4273	12.5524
GDP(UAE)	11.624	0.068	11.5434	11.7111
LPI(India)	3.28	0.061	3.22	3.4
LPI(UAE)	3.99	0.013	3.96	4.00
RE(India)	87881.5	17918.72	80743.97	120445.3
RE(UAE)	3034.3	2031.7	1935.23	5907.44
IA(India)	0.2	0.4	0	1
IA(UAE)	0.2	0.4	0	1
Trade Volume	68756.8	13718.33	43302.53	84840.34

Source: Author's own calculation using R studio

From the descriptive statistics, we observe that the trade volume (TV) has fluctuated significantly over the years for both India and the UAE, with values ranging from 43,302.53 to 84,840.34. The GDP of India and the UAE shows a gradual increase over the study period, with India's GDP ranging from 12.4273 to 12.5524 and the UAE's GDP ranging from 11.5434 to 11.7111. The Logistics Performance Index (LPI) for both countries increased slightly over the years, with India starting at 3.22 and reaching 3.40, and the UAE's LPI showing minimal variation from 3.96 to 4.00. Renewable energy use in India shows considerable variation, ranging from 80,743.97 to 120,445.3, while UAE's renewable energy data shows more modest values, ranging from 1,935.23 to 5,907.44. International agreements (IA) were mostly binary (0 or 1) in nature, with occasional fluctuations in both countries.

Principal Component Analysis (PCA)

The Principal Component Analysis (PCA) revealed the underlying structure in the data and identified key components that explain most of the variance. The results indicate that the first principal component (PC1) accounts for 97.67% of the variance in the dataset, suggesting a high correlation among GDP, LPI, and renewable energy (RE). This high explanatory power justified the use of PC1 in the regression models, ensuring the robustness of the analysis while addressing multicollinearity. The second component (Dim.2) explains only 2.10% of the variance, and the third component (Dim.3) contributes just 0.23%.

The variable contributions to the first dimension were as follows:

- GDP: 33.94%
- LPI: 32.86%
- RE: 33.20%

Given that the first principal component captures nearly all the variance, it was used as a composite index to replace the highly collinear variables (GDP, LPI, RE) in subsequent regression models.

Pooled OLS Regression

The pooled Ordinary Least Squares (OLS) regression model was estimated to examine the relationship between trade volume (TV) and the explanatory variables: GDP, Logistics Performance Index (LPI), Renewable Energy (RE), and International Agreements (IA). The results of the pooled OLS regression are summarized below.

Table 2: Pooled OLS Regression Results:

Predictor	Estimate	Std. Error	t-value	p-value
Intercept	-3.417*10 ⁶	667,910	-5.116	0.0037**
GDP	2.304*10 ⁵	48,878	4.714	0.0053**
LPI	2.023*10 ⁵	30,434	6.647	0.0012**
RE	-0.6326	0.264	-2.134	0.0859
IA	5,626.3	5,463	1.030	0.3503

Source: Author's own calculation using R studio

The pooled model indicates that GDP and LPI have a significant positive effect on trade volume (TV), with coefficients of 2.023×10^5 ($p=0.00116$) and 2.304×10^5 ($p=0.00527$), respectively. While the relationship with renewable energy (RE) is marginally negative ($p = 0.0859$). International agreements (IA) have no significant effect on trade volume ($p = 0.3503$). The model's R-squared value of 0.9037 indicates that the model explains approximately 90.4% of the variation in trade volume, suggesting a good fit. The adjusted R-squared value is 0.8267, which accounts for the number of predictors included in the model.

Lasso Regression

To mitigate the risk of overfitting and improve generalizability, a Lasso regression model was estimated using the same predictors. The regularization parameter (lambda. min) was selected via cross-validation, and the resulting coefficients for the Lasso model are presented below:

Table 3: Lasso Regression Results:

Predictor	Coefficient Estimate
Intercept	-3,380,042
GDP	227,682
LPI	200,928
RE	-0.6179955
IA	5,619.554

Source: Author's own calculation

The Lasso model results show that GDP and LPI continue to have positive coefficients and influential predictors, indicating a strong positive relationship with trade volume (TV). Renewable energy (RE) and international agreements (IA) have smaller coefficients, suggesting a reduced influence due to Lasso's regularization. The regularization parameter (λ) minimized prediction error, ensuring better generalization. RE exhibited a slight negative effect, suggesting its indirect role in trade dynamics, while IA had a minimal positive impact. The Lasso model helps reduce the impact of less significant predictors, making it more robust for prediction purposes, though the overall R-squared is expected to be lower compared to the pooled model.

Comparison of Pooled OLS and Lasso Models

A comparison of the pooled OLS and Lasso regression models highlights the differences in fit and the treatment of predictors:

- **Pooled OLS Model:** The pooled model has a high R-squared (0.9037), but the risk of overfitting exists due to the lack of regularization. It suggests that GDP and LPI have a strong impact on trade volume, while renewable energy (RE) and international agreements (IA) have weaker effects.
- **Lasso Model:** The Lasso model provides a more generalizable approach by shrinking the coefficients of less significant variables (such as RE and IA). While it typically results in a lower R-squared value, the Lasso model is less prone to overfitting, making it more suitable for prediction.

This study aimed to investigate the key drivers of bilateral renewable energy trade between India and the UAE, focusing on the roles of logistics performance (LPI), economic growth (GDP), renewable energy (RE), and international agreements (IA). The results from the Pooled OLS regression and Lasso regression methods provide valuable insights into the relationships between these variables and trade volume (TV).

1. **Logistics Performance (LPI) and Economic Growth (GDP)** were found to be the most significant drivers of trade volume. The Pooled OLS model indicated that both variables had a strong positive effect on trade, with LPI and GDP exhibiting statistical significance at p-values of 0.00116 and 0.00527, respectively. This is further reinforced by the Lasso regression, where these variables retained their significant influence despite regularization. The R-squared value of 90.37% in the Pooled OLS model also demonstrates that these factors collectively explain a substantial portion of the variation in trade volume, supporting the hypothesis that better logistics performance and economic growth enhance bilateral renewable energy trade.
2. **Renewable Energy (RE)** had a relatively weaker impact on trade volume. While included in both models, its effect was marginally significant in the Pooled OLS model ($p=0.0859$), and Lasso regression showed a negative coefficient, indicating a slight inverse relationship with trade. This suggests that renewable energy, while important, does not have as strong a direct influence on trade volume as logistics and economic factors. These findings suggest that the impact of renewable energy

on trade may be indirect, potentially influenced by other factors such as infrastructure readiness or policy frameworks.

3. International Agreements (IA) showed no significant impact on trade volume in either model. The Pooled OLS model returned a high p-value (0.35031), and the Lasso regression reduced its influence, indicating that while international agreements may play a supporting role, they do not directly drive trade volume as strongly as logistics performance or economic growth.

The findings of this study largely support the hypothesis that logistics performance and economic growth are the primary drivers of bilateral renewable energy trade between India and the UAE. However, the results also highlight the limited direct impact of renewable energy and international agreements on trade volume. These factors may interact with logistics and economic conditions, but their individual effects appear weaker in comparison. Therefore, while the hypothesis is largely accepted, further exploration is needed to understand the role of renewable energy and international agreements in shaping trade dynamics.

The descriptive statistics reveal variability in key economic and trade indicators between India and the UAE over the study period. Additionally, the Principal Component Analysis (PCA) results suggest a strong correlation among GDP, LPI, and renewable energy, which led to the use of the first principal component in the regression models. Both the Pooled OLS and Lasso regression results confirm that GDP and LPI have a significant positive relationship with trade volume. However, the Lasso regression provides a more reliable prediction by addressing potential overfitting through regularization. Collectively, the models highlight that GDP and logistics performance are key drivers of trade volume between India and the UAE, while renewable energy and international agreements have a relatively weaker impact.

Conclusion and Policy Recommendations

Conclusion

This study investigated the drivers of bilateral renewable energy trade between India and the UAE, focusing on the impact of logistics performance, renewable energy indicators, economic growth, and international agreements. By employing pooled regression and Lasso regularization techniques, some key findings emerged, Logistics Performance and Economic Growth as Primary Drivers. The pooled regression results indicate that logistics performance (LPI) and economic growth (GDP) significantly influence bilateral renewable energy trade. The high R-squared value (90.37%) underscores the importance of these factors in explaining trade variations. Lasso regression further confirmed the dominant roles of LPI and GDP by retaining them as the most influential variables, while shrinking the impact of renewable energy indicators (RE) and international agreements (IA). Renewable Energy's had a Limited Direct Impact. While renewable energy indicators (RE) were included in the analysis, their impact on trade volume was weaker compared to LPI and GDP. This suggests that renewable energy's influence on trade may be indirect or contingent upon other factors, such as infrastructure readiness or policy frameworks. A Minor Role of International Agreements, the study found that international agreements (IA) had limited statistical significance, indicating

that while they may provide a supportive framework, they do not directly drive trade volumes as strongly as logistics and economic growth.

These findings underscore the importance of logistics and economic growth in shaping bilateral trade. Leveraging these insights can support broader energy transition goals while strengthening India-UAE trade relations.

Policy Recommendations

1. **Enhancing Logistics Performance:** Governments in India and the UAE should prioritize investments in logistics infrastructure, including ports, transportation networks, and storage facilities, to streamline the trade process. Improved logistics performance can significantly enhance trade efficiency and reduce transaction costs.
2. **Fostering Economic Growth:** Economic policies fostering innovation and renewable energy investment can sustain GDP's positive trade impact. Fiscal incentives for renewable energy projects can further strengthen this linkage.
3. **Strengthening Renewable Energy Integration:** Policymakers should integrate renewable energy into trade ecosystems through subsidies, technology-sharing agreements, and harmonization of trade standards. Simplifying customs procedures and establishing bilateral research initiatives can further enhance trade.
4. **Optimizing International Agreements:** Policymakers should revisit existing agreements to incorporate actionable measures that directly facilitate trade. This could include harmonizing trade standards, simplifying customs procedures, and establishing bilateral renewable energy research initiatives.
5. **Encouraging Future Research:** Future studies should explore interaction effects between renewable energy and logistics performance, as well as the long-term impact of international agreements. Expanding the dataset to include more countries and longer time periods could provide deeper insights into these dynamics.

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