Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

Vol. 2 No. 3 (October) (2024)

Exploring the effects of Air Pollution, Renewable Energy usage, and AI-driven Technologies on Australia's Economic Development Using the ARDL Model

Muhammad Waseem Arshad
Student, School of Economics, BZU Multan, Email: mwarshad@numl.edu.pk

Iqra Bashir
Student, School of Economics, BZU Multan, Email: Iqrab8088@gmail.com

Dr. Yousaf Khan
Focal Person of Accounts, National University of Modern Languages (NUML) Regional Campus Peshawar. Email: ykhan@numl.edu.pk & Orcid: https://orcid.org/0000-0001-5698-3497

Muhammad Usman
Student, School of Economics, BZU Multan. Email: usmanramzan171@gmail.com

Sania Batool
Student, School of Economics, BZU Multan, Email: sania.akmal11997@gail.com

Abstract
This study uses the Autoregressive Distributed Lag (ARDL) model to investigate the relationship between air pollution, renewable energy usage, AI-driven technologies, and Australia's economic development over the period 2010–2020. The analysis provides important insights into the dynamic interactions between these variables in both the short and long term. Renewable energy adoption shows a negative impact on economic growth in the short term, likely due to initial investment costs and infrastructure adjustments, it demonstrates a significant positive effect on GDP in the long term. This finding underscores the critical role of renewable energy in fostering sustainable growth over extended periods. The incorporation of AI-driven technologies is found to enhance economic performance, particularly in the short term. The immediate benefits likely stem from improved productivity, cost efficiency, and the expansion of innovative industries supported by AI advancements. The study identifies a detrimental impact of air pollution on economic growth, highlighting the need for stringent environmental regulations and policies aimed at reducing air pollutants. This negative relationship emphasizes the importance of addressing environmental challenges as a core component of economic development strategies. The bounds test for co-integration confirms a stable and consistent long-term relationship among the variables. This suggests that policies addressing these factors can have enduring implications for Australia's economic trajectory. This study contributes to the discourse on sustainable economic growth by highlighting the interplay between technology, environment, and economic performance. It underscores the necessity of aligning AI and renewable energy policies to foster a balanced, sustainable development pathway.
Keywords: Artificial Intelligence, Economic Growth, Renewable Energy, Environmental sustainability, ARDL

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

Introduction

In recent years, artificial intelligence has received a lot of attention for its role in fostering environmental sustainability. As the global economy undergoes a digital transformation, the incorporation of AI-powered technologies has the potential to redefine how we handle environmental issues. Proponents of AI-driven sustainability believe that the technology can help reduce resource usage and carbon emissions in a variety of industries. For example, AI-enabled precision farming techniques can optimize water usage, reduce chemical inputs, and increase crop yields, thereby boosting agricultural practice sustainability. Similarly, AI-powered supply chain optimization can result in more efficient logistics, lowering the environmental effect of transportation and distribution (Dauvergne, 2022). However, the relationship between AI and sustainability is tricky. The potential benefits of AI in promoting environmental stewardship must be balanced with the technology's inherent environmental impact. AI systems' energy-intensive nature, as well as their fast expanding electricity usage, offer substantial concerns.

To address this paradox, a balanced and holistic strategy is required, with a focus on responsible AI development and deployment. According to the literature, the true value of AI in sustainability is its potential to enable and nurture effective environmental governance (Camaréna, 2021; Khan, Arshad, Bashir, Nadeem, & Gujjar, 2022; Nishant, Kennedy, & Corbett, 2020). By integrating AI-driven solutions with culturally relevant organizational procedures and individual habits, we can harness technology's transformative capacity to achieve real and long-term change. Meanwhile, as the globe faces the pressing dilemma of environmental sustainability, the concept of a "green economy" has gained popularity as a potential answer (Purwandani & Michaud, 2021). Australia, with its enormous natural resources and increasing emphasis on renewable energy, has emerged as a significant role in this worldwide change. (Batool, Khan, Arshad, & Bashir, 2024).

The relationship between environmentally sustainable revenue, employment, and salaries in Australia is complex. If Australia implements an environmental sustainability policy, it may result in employment losses in important areas such as energy and transportation. However, research reveals that policy choices exist to accomplish both environmental sustainability and full employment as goals for the Australian economy (Chishti, Xia, & Dogan, 2024).

A policy that balances the impact of sustainability and employment is critical, as highlighted in the paper "Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World" by Chishti et al. (2024) . The paper underlines that present policy frameworks only realize a small portion of the potential benefits for jobs and development (Tian, Li, Lee, & Spulbăr, 2024).

Research Objectives

1. To analyze the role of AI-driven technologies (proxied by ICT services) in shaping sustainable economic growth in Australia.
2. To investigate the impact of renewable energy adoption and environmental degradation (proxied by air pollution) on Australia’s economic sustainability.

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

Vol. 2 No. 3 (October) (2024)

3. To provide strategic insights for policymakers on balancing economic growth, technological advancements, and environmental sustainability

Research Questions

1. How might AI contribute to Australia's long-term economic growth?
2. What is the relation between renewable energy usage, air pollution, and economic growth in Australia?
3. How can Australia integrate technical advancements, environmental aims, and economic strategies for sustainable development?

Literature review

Trammell and Korinek (2023) analyzed models that capture the idea that AI will allow capital to "self-replicate" via increasing capital's substitutability for labor or by automating tasks, for example, to enhance output production. Usually, this increases growth and decreases the labor share. Trammell and Korinek (2023) analyze experimentally how private investments in the AI sector and developments linked to AI have affected the annual growth of the U.S. Gross Domestic Product (GDP) between 2010 and 2020. The dependent variable is the annual percentage change in the U.S. GDP, adjusted for inflation, using data from the Center for Security and Emerging Technology (CSET) and the International Monetary Fund (IMF). Annual private investment in AI and the quantity of patents applications and a number of US industries, including banking and finance, life sciences, and Energy Administration pertaining to AI are examples of independent variables.

Qin, Xu, Wang, and Skare (2024) talked about how AI and economic growth interact. In particular, we use a two-phase process. The most pertinent source is the journal "Sustainability," according to the biblio metric analysis's results, which indicate that the number of publications in the field has increased dramatically in recent years. Furthermore, the main avenues for future study are in deep learning and data mining.

Korinek and Stiglitz (2021) examined the underlying economic dynamics of this shift and proposed measures to reduce their negative impacts on underdeveloped and emerging markets while maximizing the potential benefits of technological advancements(Ahmad, Khan, Hussain, Khan, & Khan).

Nayal, Raut, Queiroz, Yadav, and Narkhede (2023) proposed conceptual study that examined several arguments and difficulties around big data driven by AI and its effects. It primarily focuses on the theoretical difficulties that the labor theory of value faces and how they affect society and the economy from a critical standpoint. By examining potential future trends and advancements for the sustainable application of AI, it also provides alternatives.

Ahmed and Shimada (2019) determined the relationship between the use of renewable energy sources and the development of a sustainable economy in emerging and developing nations. The World Bank's World Development Indicators (WDI), Ernst and Young's Renewable Energy Country Attractiveness Index (RECAI), and a random selection method based on the current trend of renewable energy consumption for five different regions of the world—Asia, South Asia, Latin America, Africa, and the Caribbean—are used in this paper to select a panel of thirty emerging and developing nations. With the exception of

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

Latin American and Caribbean nations, the panel's results indicate a strong long-term correlation between the use of renewable energy and economic growth in a number of South Asian, Asian, and most African countries (such as Ghana, Tunisia, South Africa, Zimbabwe, and Cameroon).

DU CIEM (2022) showed that greater interest rates and power tariffs together with higher technology values and SPC participation rates will translate into larger ROI. Technology based on renewable energy might be applied to value-added activities in rural regions, promote small businesses, give locals employment possibilities, and establish the framework for long-term, sustainable economic growth. But watchfulness is necessary because trash from tiny enterprises can also contribute to pollution.

Kazar and Kazar (2014) studied the association between development and renewable electricity net generating values has been investigated using panel analysis, with the human development index being used as a measure of development level and taking data from two distinct time periods: 1980–2010 for the long term (five years) and 2005–2010 for the short term (years). It was discovered that while there is a short-term bidirectional causal relationship between renewable energy production and economic development, long-term economic progress will lead to the generation of renewable energy.

Tishkov et al. (2020) determined the socio-economic effects of switching from conventional to renewable energy sources, research how other countries have implemented policies related to renewable energy, assess the potential and prospects for renewable energy with particular emphasis on rural northern areas. An estimation was made of the prospective expansion of the renewable energy sector in Russia, with a focus on the Northwestern macro-region. The energy policy that is being established needs to be oriented toward the environment and the economy in order to ensure socioeconomic security.

An empirical strand that consists of ad hoc specifications and estimations of a reduced form equation that relate income per capita to an environmental impact indicator; and a theoretical strand that consists of macroeconomic models of the interaction between environmental degradation and economic growth, such as overlapping generations, optimal growth, and endogenous growth models (Batool et al., 2024; Khan & Arshad, 2024). The author comes to the conclusion that the empirical results of the Environmental Kuznets Curve literature are largely supported by the macroeconomic models.

Costantini and Monni (2008) stated that while the Environmental Kuznets Curve (EKC) includes the effects of economic growth on environmental quality, the Resource Curse Hypothesis (RCH) primarily analyzes the effects of natural resource endowment on economic growth. In addition, new research on RCH and EKC has demonstrated the significance of institutions and aspects of human development in creating a route toward sustainable development. In this essay, we seek to examine the causal connections among sustainability, human development, and economic progress(Khan, Saqib, & Ahmad, 2016).

The environmental Kuznets curve EKC hypothesis for industrial water contamination is tested by Hettige, Mani, and Wheeler (2019), they assessed how income growth affects three indicators of pollution: the proportion of industry in the country's production, the proportion of industries that produce pollutants in the industrial output, and the "end-of-pipe" (or "end-of-pipe") pollution

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

Vol. 2 No. 3 (October) (2024)

intensities per unit of output in the industries that produce pollutants. It was observed that whereas the other two determinants do not follow a Kuznets-type trajectory, the industrial share of national output does. When taken as a whole, our findings suggest that the EKC hypothesis—which states that industrial water pollution grows quickly until middle-class status and then stays relatively constant—is rejected.

Author(s)	Year	Focus of Study	Key Findings	Relevance to Research
Korinek & Trammell	2023	AI's impact on labor and capital substitution	AI automates tasks, reducing labor share while boosting growth	Encourages AI's role in enhancing economic output
Vijaykumar	2021	AI investments and U.S. GDP growth	Private AI investments positively impacted GDP from 2010–2020	Explicit the economic potential of AI
Skare et al.	2024	Bibliometric analysis of AI and economic growth	Deep learning and data mining are key areas for future research	Highlights emerging AI research directions
Stiglitz & Korinek	2021	Economic dynamics of AI in emerging markets	Advocates policies to minimize negative impacts and maximize benefits	Provides policy insights for sustainable AI use
Nayak	2021	Big data, AI, and societal impacts	Explores challenges with labor theory and suggests sustainable AI alternatives	Addresses critical social aspects of AI development
Shimanda & Ahmed	2019	Renewable energy and sustainable economic growth	Strong long-term correlation between renewable energy use and economic growth in developing countries	Links renewable energy with sustainable growth
Gaile et al.	2019	Renewable energy technology in rural development	Technology boosts local businesses and employment but requires careful waste management	Supports sustainable economic practices
Kazar & Kazar	2014	Relationship between renewable energy and development	Bidirectional short-term causality between energy and development; long-term growth drives energy generation	Useful for understanding energy-economy dynamics
Pakhomova et al.	2020	Transition to renewable energy in Russia	Emphasizes socio-economic security in energy policies	Provides insights on energy policy frameworks

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

Panayotou	2000	Environmental Kuznets Curve (EKC) and economic growth	Confirms EKC patterns in macroeconomic models	Links environmental degradation with income levels
Monni & Costantini	2006	EKC, resource curse, and human development	Human development and institutions are essential for sustainable growth	Shows institutional importance in sustainable development
Wheeler et al.	2000	EKC hypothesis for industrial water pollution	EKC holds only for industrial share of national output	Explores environmental limits to economic growth

Research gap

Only a few research have looked at the Australian context, despite earlier studies looking at the effects of AI on economic growth (Korinek & Stiglitz, 2021) and the significance of renewable energy and environmental elements in sustainable development (Kazar & Kazar, 2014). Furthermore, research has mostly addressed environmental and economic variables independently, failing to incorporate environmental sustainability, renewable energy, AI (represented by ICT), and other aspects into a cohesive framework. By examining their interrelated impacts on Australia's economic growth and use ARDL modeling to reveal both short- and long-run dynamics, this study closes these gaps (Lanhui & Ibrahim, 2024).

Data & Methodology

This study uses annual data for Australia **from 2014 to 2023, obtained from the World Development Indicators (WDI)** database. The selected variables reflect the interaction between technological innovation, environmental quality, and economic development, aligning with Australia's sustainability and economic growth goals (Khan, 2022b; Khan, Shad, & Irfan, 2022; Mumtaz, Ahmad, & Khan, 2021; D. Yousaf Khan, Ahmad, & Malik, 2021; M. I. Yousaf Khan & Khan, 2020).

Variable Name	Measurements	Sources	Reference
Dependent Variable			
GDP	Per capita (constant 2015 US$)	WDI	Gajdosova et all., 2023 measured economic growth by using GDP
Independent Variable			

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

ICT	Goods exports (% of total goods exports)	WDI	(Qin et al., 2024)., Determined a **novel framework** in order to assess AI's economic growth role by using ICT as a reliable proxy.
Renewable Energy Consumption	(% of total final energy consumption)	WDI	Henrick Lund,. 2007 explored Renewable energy strategies for sustainable growth
Air pollution	PM2.5 air pollution	WDI	Urpelainen et all., 2020 measured environmental degradation by taking air pollution

Econometric Model
GDP = f (ICT, REC, AP,)………. (i)

Where GDP represents Gross Domestic product, ICT as the proxy for AI, REC as renewable energy consumption and AP as the air pollution.

$GDP_t = \xi_0 + \xi_{01}ICT_t + \xi_{02}REC_t + \xi_{03}AP_t + \mu_t$ **… (ii)**

At first, Unit root test will be applied to check the stationarity of our variables. Later, to explore both the short-run and long-run relationships among these variables, the Autoregressive Distributed Lag (ARDL) technique is employed. The ARDL model is suitable for small sample sizes and datasets with variables of mixed stationarity (I(0) and I(1)). This approach allows for:

1. Short-run dynamics: Immediate effects of ICT, renewable energy, and air pollution on GDP.
2. Long-run relationships: The equilibrium relationship among the variables over time

Unit root test

Variables	Test of unit root in	Include the test equation	ADF statistics T-statistics	p-values	Phillip Perron T-statistics	P-Values
GDP	Level	Intercept	-3.3411*	0.0539	-3.6616	0.0002
ICT	First difference	Intercept	-3.2546*	0.0623	-3.9567	0.0048
Renewable Energy	First difference	Intercept	-3.0673*	0.0280	-5.5016	0.0001
Air pollution	Level	Intercept	-5.8824*	0.0035	-4.2213	0.0113
* Represents the level of significance of the variables at 1%.						

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

Interpretation

The unit root test findings show a combination of stationary and no stationary variables. Both the ADF and Phillips-Perron (PP) tests show that GDP and air pollution are stationary at significant p-values (PP: 0.0002 and 0.0113). In contrast, ICT and Renewable Energy become stationary only at the first difference, as seen by their ADF and PP test findings (PP for ICT: 0.0048, PP for Renewable Energy: 0.0001). This combination of I(0) and I(1) variables enables the usage of the ARDL model, which can handle variables with different integration orders (Bergougui, 2024; Khan, Ahmad, & Malik, 2022).

Descriptive statistics

Description	GDP	ICT	RENEWABLE ENERGY	AIR POLLUTION
Mean	4.767417	0.112733	1.397263	7.124899
Median	4.765974	0.079332	1.403632	7.128628
Maximum	4.787749	0.274158	1.439064	7.16141
Minimum	4.750826	0.017033	1.348757	7.090617
Std. Dev.	0.012153	0.092464	0.02866	0.022682
Skewness	0.41836	0.560469	-0.04682	-0.00662
Kurtosis	2.172443	1.858311	2.189115	1.944923
Jarque-Bera	0.577062	1.066648	0.277626	0.463901
Probability	0.749363	0.586652	0.870391	0.792985
Sum	47.67417	1.127333	13.97263	71.24899
Sum Sq. Dev.	0.001329	0.076946	0.007392	0.00463
Observations	10	10	10	10

Interpretation

The descriptive statistics for the GDP, ICT, Renewable Energy, and Air pollution reveal several key insights about the dataset. The means of the variables are close to their medians, indicating a relatively symmetrical distribution. The standard deviations are small across all variables, suggesting limited variability within the dataset (Ayaz, Khan, & Shad, 2022; Batool et al., 2024; Khan, Ahmad, & Awan, 2022).

1. Skewness values are near zero, showing that the distributions for most variables are fairly symmetric, with GDP and ICT slightly positively skewed, while Renewable Energy and Air pollution are almost perfectly symmetrical.
2. The kurtosis values are below 3, indicating that the distributions are flat (platykurtic) with fewer extreme outliers.
3. The Jarque-Bera test results show high p-values (all above 0.5), suggesting no significant departure from normality.

In summary, the dataset is normally distributed, with low variability and no extreme Skewness or kurtosis, making it appropriate for further econometric analysis like ARDL without the risk of significant distortion due to outliers or abnormal distribution.

Correlation Analysis

Var	GDP	ICT	RENEWABLE	AIR

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

			ENERGY	POLLUTION
GDP	1			
ICT	0.557131	1		
RENEWABLE ENERGY	0.720221	0.382331	1	
AIR POLLUTION	0.959705	0.480335	0.714067	1

Interpretation

The correlation matrix shows a strong positive association between the variables. The GDP is highly correlated with the AIR POLLUTION (0.9597) and RENEWABLE ENERGY (0.7202), indicating that increases in the labor force and industrial growth significantly boost GDP. The ICT (0.5571) has a moderate correlation, indicating that while ICT positively impacts economic growth, its effect is less pronounced than labor and industry. The ICT has a weaker correlation with renewable energy (0.3823) and a moderate correlation with air pollution (0.4803), indicating that ICT development is linked to labor participation but not industrial expansion.

Overall, these connections indicate that focusing on labor and industrial policies is critical for increasing GDP, although integrating ICT is still vital for balanced growth.

Lag Selection and ARDL Model Estimation (First ARDL Test)
Method: ARDL

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOG_OF_GDP(-1)	1.161951	0.048384	24.01544	0.0017
LOG_OF_GDP(-2)	0.909599	0.149190	6.096937	0.0259
LOG_OF_ICT	0.108243	0.005634	19.21289	0.0027
LOG_OF_RENEWABLE_ENERGY	-0.335439	0.031533	-10.63776	0.0087
LOG_OF_AIR_POLLUTION	-0.724947	0.116603	-6.217224	0.0249
C	-4.165022	0.649868	-6.409023	0.0235

This test is considered necessary to build a reliable model. The ARDL model analysis, using GDP as the dependent variable, shows a strong link between economic growth and the independent factors. The study found significant coefficients for GDP(-1) (1.162) and LOG_OF_GDP(-2) (0.910), indicating a strong correlation between historical and current GDP levels and economic growth. The ICT coefficient is positive and significant (0.108), demonstrating that increased ICT leads to GDP growth. RENEWABLE_ENERGY (-0.335) and AIR_POLLUTION (-0.725) have a negative influence on GDP, indicating that higher levels of renewable energy and air pollution lead to slower economic growth. The model explains a substantial fraction of GDP variance (R-squared = 0.9987), indicating a strong fit(Khan, 2022a). Overall, the findings emphasize the complicated relationships between technology, sustainability, and economic performance, with ICT positively boosting growth while renewable energy and air pollution have a negative impact.

ARDL Bounds Test and Co-integration (Least Squares Output)

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

ARDL Bounds Test

F-statistics Critical Values	K		Range
6.2232 1(1)bound	3		1(0)bound
3.77		10%	2.72
4.35		5%	3.23
5.61		1%	4.29

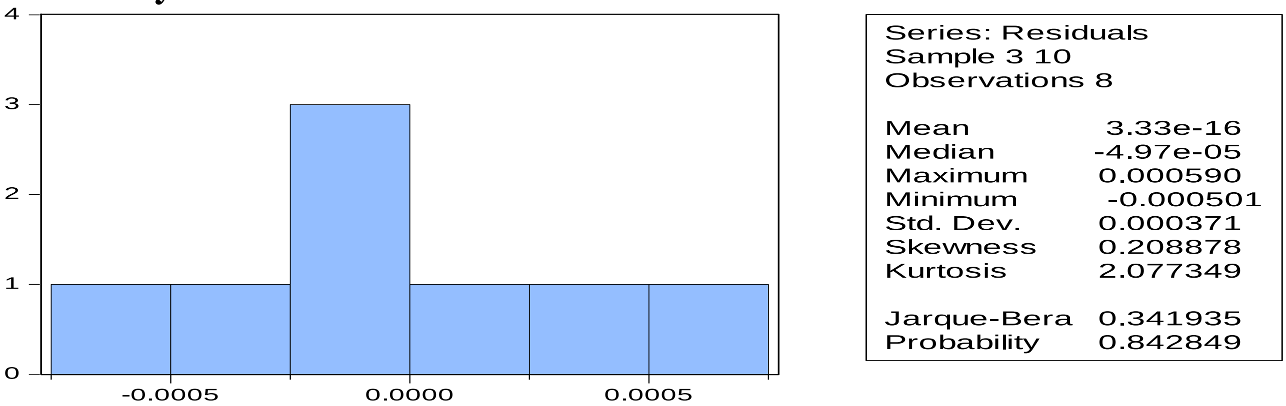
The ARDL bounds test results indicate that the variables have a long-run relationship. The F-statistic is 6.2233, exceeding the critical value boundaries at the 5% level (4.35). This results in the rejection of the null hypothesis, which states that no long-run correlations exist between the variables. In summary, the test indicates that GDP and the independent variables (ICT, renewable energy, and air pollution) have a stable long-run equilibrium connection, indicating that the ARDL model is adequate for further research.

ARDL LEAST SQUARE (ALS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LOG_OF_GDP(-1))	-0.371957	1.876055	-0.198265	0.8612
C	2.728916	2.902092	0.940327	0.4463
LOG_OF_ICT(-1)	0.057465	0.117818	0.487744	0.6740
LOG_OF_RENEWABLE_ENERGY(-1)	0.053930	0.237058	0.227498	0.8412
LOG_OF_AIR_POLLUTION(-1)	-0.810320	1.303439	-0.621678	0.5976
LOG_OF_GDP(-1)	-0.443025	0.742262	-0.596858	0.6112

A Least Squares regression was used as part of the ARDL Bounds Test to see if the variables have a long-run connection. The F-statistic from the test surpassed the threshold boundaries, indicating the presence of co-integration.

Normality Test



Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

The histogram of the residuals from the ARDL model shows that the distribution is generally symmetrical about zero, implying that the model's residuals are not severely biased. The residuals' mean and median are quite near to zero, demonstrating the model's ability to capture the underlying trends. The Skewness is modest (0.208878), indicating minor asymmetry, and the kurtosis (2.077349) shows a generally normal distribution. The Jarque-Bera statistic (0.341935) with a high probability value (0.842849) indicates that we cannot reject the null hypothesis of normality for the residuals, implying that they are normally distributed. Overall, this contributes to the model's reliability.

ARDL ECM and Long-Run/Short-Run Dynamic

ARDL - And Short run & Long Run Form				
Short run model and Co-integrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP(-1))	-0.909599	0.149190	-6.096937	0.0259
D(ICT)	0.108243	0.005634	19.212886	0.0027
D(RENEWABLE_ENERGY)	-0.335439	0.031533	-10.637756	0.0087
D(AIR_POLLUTION)	-0.724947	0.116603	-6.217224	0.0249
CointEq(-1)	1.071551	0.145226	7.378513	0.0179
Cointeq = LOG_OF_GDP - (-0.1010*LOG_OF_ICT + 0.3130				
*LOG_OF_RENEWABLE_ENERGY + 0.6765*LOG_OF_AIR_POLLUTI				
ON + 3.8869)				
Long Run Model				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
ICT	0.101015	0.010712	-9.430018	0.0111
RENEWABLE_ENERGY	0.313041	0.016098	19.446148	0.0026
AIR_POLLUTION	-0.676540	0.128522	5.264023	0.0342
C	3.886911	0.115842	33.553526	0.0009

The ARDL cointegration results show a strong long-term link between LOG_OF_GDP and the independent variables. The error correction term (CointEq(-1) = 1.0716) is significant (p = 0.0179), indicating long-term cointegration between variables. The coefficient for D(GDP(-1)) is -0.9096, indicating that historical GDP values have a negative impact on current GDP, illustrating adjustment processes in short run. D(ICT) has a positive influence on GDP (0.1082, p = 0.0027) in short run, demonstrating that increased ICT promotes economic growth. D(RENEWABLE_ENERGY) (-0.3354) and D(AIR_POLLUTION) (-0.7249) both have a negative impact on GDP shortly, suggesting that increased usage of renewable energy and air pollution leads to slower economic growth.

In the long run, the coefficients for ICT (-0.1010) and AIR_POLLUTION (0.6765) show positive and negative associations with GDP, respectively. Camaro et all, 2021 analyzed the positive impact of AI represented by ICT on economic growth in Japan, China, India and Singapore, confirming our obtained results in the right direction. Meanwhile, Pal et all 1990, found an inverse relationship among environment degradation represented by air pollution and economic growth. The variable RENEWABLE_ENERGY shows a positive long-run coefficient (0.3130), implying that rising renewable energy use correlates with economic growth (Batool et al., 2024). Ayub et all 2024 represented renewable energy's positive role along with other variables on economic growth in long run also (Minghai, Khan, Khalil, Khan, & Marwat, 2024). Overall, our findings demonstrate the complex linkages between technology, environmental issues, and economic performance, underlining the necessity of managing air pollution and boosting renewable energy for sustainable growth.

Diagnostic Test

	Results
R-squared	0.9987
Adj.R-squared	0.9955
Durbin-Watson	2.5450
LM test	0.2173
Jarque-Bera	0.3419
Hetero	0.3514
Ramsey reset	0.3301

Policy Implications and Conclusion

The study's conclusions emphasize the significance of renewable energy, artificial intelligence (AI), and air quality in promoting sustainable economic growth in Australia. While renewable energy has early negative effects but eventually adds to long-term growth, ICT development has a favorable short-term influence on GDP. Nonetheless, economic performance is adversely impacted by air pollution, highlighting the necessity for more stringent environmental regulations.

Adoption of AI and digital infrastructure should be encouraged by policymakers in ways that support sustainability objectives. Increasing the usage of renewable energy will reduce environmental hazards and promote long-term economic resilience. Securing more robust regulatory frameworks to combat air pollution is crucial to striking a balance between environmental preservation and economic advancement. In order to accomplish Australia's long-term growth and sustainability goals, it will be necessary to adopt a green digital economy framework that will guarantee technical breakthroughs, clean energy regulations, and environmental sustainability function in harmony (Abdullah et al., 2024).

References

Abdullah, K., Kaushal, J. B., Takkar, S., Sharma, G., Alsafwani, Z. W., Pothuraju, R., . . . Siddiqui, J. A. (2024). Copper metabolism and cuproptosis in human malignancies: Unraveling the complex interplay for therapeutic insights. *Heliyon*.

Ahmed, M. M., & Shimada, K. (2019). The effect of renewable energy consumption on sustainable economic development: Evidence from emerging and developing economies. *Energies, 12*(15), 2954.

Ayaz, B., Khan, Y., & Shad, F. (2022). Investigating the Spillover Effects of the US Interest Rate on CO2 Emissions. A Case of a Developing Country. *Abasyn University Journal of Social Sciences, 15*(2).

Batool, S., Khan, Y., Arshad, M. W., & Bashir, I. (2024). Analyzing the Influence of Global Energy Price Fluctuations on Stock Indices in BRICS-T Nations. *Social Science Review Archives, 2*(2), 286-297.

Bergougui, B. (2024). Investigating the relationships among green technologies,

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

financial development and ecological footprint levels in Algeria: Evidence from a novel Fourier ARDL approach. *Sustainable Cities and Society, 112*, 105621.

Camaréna, S. (2021). Engaging with artificial intelligence (AI) with a bottom-up approach for the purpose of sustainability: Victorian farmers market association, Melbourne Australia. *Sustainability, 13*(16), 9314.

Chishti, M. Z., Xia, X., & Dogan, E. (2024). Understanding the effects of artificial intelligence on energy transition: The moderating role of Paris Agreement. *Energy Economics, 131*, 107388.

Costantini, V., & Monni, S. (2008). Environment, human development and economic growth. *Ecological economics, 64*(4), 867-880.

Dauvergne, P. (2022). Is artificial intelligence greening global supply chains? Exposing the political economy of environmental costs. *Review of International Political Economy, 29*(3), 696-718.

DU CIEM, S. (2022). WORKING GROUP OF FISHERIES ACOUSTICS, SCIENCE AND TECHNOLOGY (WGFAST).

Hettige, H., Mani, M., & Wheeler, D. (2019). Industrial pollution in economic development: the environmental Kuznets curve revisited *The economics of water quality* (pp. 27-58): Routledge.

Kazar, G., & Kazar, A. (2014). The renewable energy production-economic development nexus. *International Journal of Energy Economics and Policy, 4*(2), 312-319.

Khan, Y. (2022a). The Socio-Cultural Factors Influence on Women's Ability to Become Social Entrepreneurs. *Competitive Education Research Journal, 3*(1), 135-146.

Khan, Y. (2022b). The sophisticated role of accounting information system (AIS) on the performance of Small and medium-sized enterprises (SMEs): Evidence from an emerging economy. *Competitive Social Science Research Journal, 3*(2), 199-214.

Khan, Y., Ahmad, W., & Awan, S. H. (2022). The Hijab Consumer Attitude toward Hijab Fashion Brand: A Case of the Developing Country. *Journal of Social Sciences Review, 2*(4), 125-137.

Khan, Y., Ahmad, W., & Malik, F. (2022). THE INFLUENCE OF CORPORATE GOVERNANCE ON ACCOUNTING CONSERVATISM IN TOP NON-FINANCIAL FIRMS OF PSX: THE MODERATING ROLE OF AUDIT QUALITY. *Competitive Social Science Research Journal, 3*(1), 321-340.

Khan, Y., & Arshad, M. W. (2024). Investigating How Customers Act and Formulate Opinions About Homemade Green Products in the Context of an Emerging Economy. *Journal of Business and Management Research, 3*(1), 731-742.

Khan, Y., Arshad, M. W., Bashir, I., Nadeem, M., & Gujjar, M. U. R. (2022). Studying Audit Quality as a Link between Accounting Conservation and Aggregated Accounting-based Earnings Quality: Theoretical and Empirical Perspectives from Emerging Economy.

Khan, Y., Saqib, M., & Ahmad, A. (2016). Cash holdings and business group membership in Pakistan. *The Discourse, 2*(2), 75-83.

Khan, Y., Shad, F., & Irfan, M. (2022). Leisure Consumer Compensatory Behavior in the Era of New Normal COVID-19. *Compet. Educ. Res. J, 3*,

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

Vol. 2 No. 3 (October) (2024)

176-192.

Korinek, A., & Stiglitz, J. E. (2021). Artificial intelligence, globalization, and strategies for economic development: National Bureau of Economic Research.

Lanhui, W., & Ibrahim, A. S. (2024). Unraveling the environmental consequences of trade openness in South Africa: a novel approach using ARDL modeling. *Environmental Research Communications, 6*(5), 055011.

Minghai, Y., Khan, W. A., Khalil, K., Khan, Y., & Marwat, A. (2024). DOES GREEN FINANCE PROMOTE ENVIRONMENT PERFORMANCE? EVIDENCE FROM PAKISTAN. *Remittances Review, 9*(1).

Mumtaz, M., Ahmad, W., & Khan, Y. (2021). Determinants of Corporate Cash Holdings in Hospitality Sector of United States of America: Using Two-Step System GMM. *Global Management Sciences Review, VI, 6*, 25-35.

Nayal, K., Raut, R. D., Queiroz, M. M., Yadav, V. S., & Narkhede, B. E. (2023). Are artificial intelligence and machine learning suitable to tackle the COVID-19 impacts? An agriculture supply chain perspective. *The International Journal of Logistics Management, 34*(2), 304-335.

Nishant, R., Kennedy, M., & Corbett, J. (2020). Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. *International Journal of Information Management, 53*, 102104.

Purwandani, J. A., & Michaud, G. (2021). What are the drivers and barriers for green business practice adoption for SMEs? *Environment systems and decisions, 41*(4), 577-593.

Qin, Y., Xu, Z., Wang, X., & Skare, M. (2024). Artificial intelligence and economic development: An evolutionary investigation and systematic review. *Journal of the Knowledge Economy, 15*(1), 1736-1770.

Tian, L., Li, X., Lee, C.-W., & Spulbăr, C. (2024). Investigating the asymmetric impact of artificial intelligence on renewable energy under climate policy uncertainty. *Energy Economics, 137*, 107809.

Tishkov, S., Scherbak, A., Volkov, A., Karginova-Gubinova, V., Tleppaev, A., & Pahomova, A. (2020). Assessment the role of renewable energy in socio-economic development of rural and Arctic regions. *Tishkov, S., Shcherbak, A., Karginova-Gubinova, V., Volkov, A., Tleppayev, A., Pakhomova, A*, 3354-3368.

Trammell, P., & Korinek, A. (2023). Economic growth under transformative AI: National Bureau of Economic Research.

Yousaf Khan, D., Ahmad, W., & Malik, F. (2021). Does Audit Quality Moderate the Nexus Between Corporate Governance and Accounting Earnings Quality in Emerging Economies. *Indian Journal of Economics and Business, 20*(4).

Yousaf Khan, M. I., & Khan, M. A. (2020). Corporate social responsibility, earnings management and financial performance: evidence from Pakistani's registered firms.