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# Evaluating Technology Improvement in Sustainable Development Goals by Analysing Financial Development and Energy Consumption in Jordan

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**ABSTRACT**

Sustainable development has become a crucial goal for policymakers worldwide, with technological progress playing a significant role in achieving this objective. Jordan, a developing country in the Middle East, has been working towards the attainment of Sustainable Development Goals (SDGs) by leveraging technology to promote economic growth while preserving the environment. In this study, we evaluate the impact of technological improvements on SDGs in Jordan by analyzing the relationship between financial development, energy consumption, and economic growth. The analysis covers the period from 1970 to 2021 and employs three econometric techniques, namely the Lee and Strazicich (2013) second-generation econometric approach, the novel Augmented Autoregressive Distributed Lag (AARDL) model, and Frequency Domain Causality (FDC) analysis. The results indicate a positive and significant association between financial development, energy use, and economic growth, with financial development having the strongest impact. Moreover, technological progress plays a crucial role in achieving SDGs by positively affecting financial development, energy consumption, and economic growth. This study highlights the importance of leveraging technology to promote sustainable development and provides valuable insights for policymakers in Jordan and other developing countries.

**Keywords:** Augmented Autoregressive Distributed Lag, Economic Growth, Energy Consumption, Financial Development, SDGs
**JEL Classifications:** B23, F43, Q43, O16, Q01

## 1. INTRODUCTION

Economic, social, and environmental development are all included in the notion of sustainable development. The Sustainable Development Goals have been implemented as a result of the United Nations' (UN) recognition of the significance of sustainable development (SDGs). The UN General Assembly approved the 17 Sustainable Development Goals (SDGs) in 2015 with the intention of advancing sustainable development on a global scale (United Nations, 2015). The SDGs address a number of issues, such as reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below the waterline, life on land, peace, justice, and strong institutions, as well as issues like hunger, poverty, health, education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth (United Nations, 2015). These objectives offer a framework for nations to work towards sustainable development, and because they are interconnected and interwoven, advancement towards one objective may have a favourable impact on other objectives. The significance of technology innovation in achieving the SDGs has recently gained more attention. Many of the problems that beset emerging nations, such as poverty, lack of access to energy, and poor infrastructure, can be solved with the help of technology (Sachs et al., 2017). For instance, digital technology can provide access to services like education and healthcare, while renewable energy technologies can give people in distant and neglected places affordable and clean electricity (Sachs et al., 2017). In the context of reaching the SDGs, the interaction between technology, financial development, energy use, and economic growth is complicated and varied. As a result, this study examines the connection between Jordan's economy, financial development, and energy use in order to assess the effect of technology advancement on the accomplishment of the SDGs.

The study employs the Autoregressive Distributed Lag (ARDL) approach, which is a second-generation econometric technique that has gained popularity in recent years due to its ability to handle nonstationary data and accommodate small sample sizes (Pesaran et al., 2001). The study will also use the novel Augmented ARDL (AARDL) and Frequency Domain Causality (FDC) methods to further explore the relationships between the variables of interest. Throughout the last few decades, Jordan, a small Middle Eastern country, has undergone a dramatic urban transformation. Due to the nation's rapidly expanding population, urbanisation has emerged as a serious problem. Jordan has faced various difficulties as a result of the urbanisation process, including an increase in energy consumption, financial progress, and technological advancement, all of which have hampered the country's economic expansion. This essay will examine Jordan's urbanisation process and the interplay between monetary expansion, energy consumption, technical advancement, and economic expansion. According to the World Bank, Jordan has recently seen strong urban growth, with the urban population increasing from 65.5% in 2000 to 86.7% in 2020. (2021). Many problems for the nation have resulted from this rapid urbanisation, including increased energy consumption, environmental degradation, and inadequate infrastructure. Jordan has therefore been making efforts to solve these issues and advance sustainable urban growth. The rise in energy usage is one of the major issues facing Jordan's urban transformation. Residential, commercial, and industrial energy demands have significantly increased as a result of urban regions' fast growth. Jordan's energy usage has climbed by 57% since 2000, according to the International Energy Agency (IEA), reaching 11.3 million tonnes of oil equivalent in 2019 (Albatayneh, 2022). Jordan's energy sector, which depends heavily on imports and has little domestic energy resources, is under strain as a result of the rise in energy consumption. In order to diversify its energy supply and encourage the usage of renewable energy, Jordan has been taking action. Financial development is a crucial component of Jordan's urban transformation. Infrastructure investments in areas like transportation, water supply, and waste management are crucial to the urbanisation process. The country has been striving to attract foreign investment to finance infrastructure development and assist economic growth. According to the World Bank, Jordan has achieved considerable advancements in its financial growth, coming in at 80th place overall out of 190 nations in the Ease of Doing Business Index (World Bank, 2021). Yet, political unrest in the area and a lack of openness in the economic climate make it difficult for Jordan to draw in foreign investment.

Another important element in Jordan's urban shift is technological advancement. For the purpose of enhancing the effectiveness of urban infrastructure and services, the nation has been attempting to incorporate new technology. The "Jordan Vision 2025" policy, which seeks to transform Jordan into a knowledge-based economy, is just one of the measures the government has made to foster technological advancement. The plan focuses on the growth of the ICT industry, which is anticipated to be essential to the nation's economic development. The economic development of Jordan has been significantly impacted by the country's urbanisation. According to data from the World Bank, Jordan's GDP increased by 2.6% year on average between 2010 and 2019, with the services sector making up the greatest portion of the economy (World Bank, 2021). The nation must overcome a number of obstacles to achieve sustainable economic growth, including a high unemployment rate, a dearth of natural resources, and a difficult business climate.

To sum up, Jordan's urbanisation has created both enormous obstacles and opportunities for the nation. An all-encompassing strategy for sustainable development is necessary due to the interconnectedness of the rise in energy consumption, financial development, technical advancement, and economic expansion. Jordan has been making efforts to address these issues, including encouraging the use of renewable energy, luring foreign investment, implementing new technology, and starting programmes to shift the economy to one based on knowledge. To achieve sustainable urban development, the nation still has to overcome a number of obstacles, including tackling environmental degradation, enhancing infrastructure, and fostering a climate that is investment-friendly for businesses. To solve these issues, policies and strategies that emphasise sustainable development, encourage innovation, and offer financial incentives for private sector participation must be created and put into action. Jordan has achieved strides in a few areas, such the adoption of renewable energy sources and urban planning, but more work needs to be done to make sure the nation's urbanisation is inclusive and sustainable. To solve these issues and achieve sustainable urban development in Jordan, cooperation and partnership between the public and commercial sectors, as well as with foreign organisations and other stakeholders, can be extremely important.

## 2. LITERATURE REVIEW

In recent years, sustainable development has become a major concern as many nations strive for sustainable economic and social development. Jordan is no different, as the nation has been pursuing sustainable development through a number of initiatives and regulations. Using technology to boost economic growth and cut down on energy use is one approach to do this. The studies that have recently examined the connection between technology, sustainable development, financial development, and energy consumption in Jordan are reviewed in this section. Alkhateeb et al. (2021)'s study looked at how Jordan's sustainable development has been impacted by technological advancement. According to the study, technology contributes to sustainable development by lowering energy use and fostering economic growth. The study also emphasised the need for policy changes to promote technology adoption for sustainable development. Alkhteb et al. (2021) looked at the effect of financial development on sustainable development in Jordan in another study. The study discovered that because it boosts economic growth and lowers poverty, financial development has a favourable effect on sustainable development. The study suggested that in order to achieve sustainable development, policymakers should concentrate on enhancing financial development. Similar research examined the link between Jordan's economic growth and energy usage by Alsmadi and Al-Assaf (2021). The study's conclusion that energy use influences economic growth suggests that the nation should concentrate on lowering its energy use in order to achieve sustainable development. Al-Khaldi et al. (2021) also looked at the effect of renewable energy on Jordan's economic development. The study concluded that the usage of renewable energy has a favourable effect on economic growth and that the nation should encourage its use in order to achieve sustainable development. Al-Madi et al. (2021) also looked at the effect of technology advancement on Jordan's economic development. According to the report, technical advancement has a good effect on economic growth, thus the nation should concentrate on utilising technology to achieve sustainable development. The effect of foreign direct investment (FDI) on economic growth and sustainable development in Jordan was also the subject of a study by Hossain et al. in 2021. According to the report, FDI contributes to sustainable development and economic progress, hence the nation should concentrate on luring more FDI in order to achieve sustainable development. The literature analysis concludes by emphasising the role that technology, financial growth, and energy consumption have in Jordan's pursuit of sustainable development. According to the papers we analysed, in order to achieve sustainable development, policymakers should prioritise enhancing financial development, lowering energy consumption, encouraging the use of renewable energy sources, and increasing FDI. Future policy initiatives aiming at attaining sustainable development in Jordan can be informed by these insights.

## 3. RESEARCH METHODOLOGY

### 3.1. Data

The present research utilizes secondary time-series data spanning from 1970 to 2021. The Gross Domestic Product (GDP) in current USD serves as the measure of economic growth, while Energy Consumption (EC) is gauged by Energy use (kg of oil equivalent per capita). The measurement of Financial Development (FD) relies on principal component analysis, considering domestic credit by bank, domestic credit by private sector, market capitalization, lending rate, and broad money supply. Lastly, the Innovation metric is employed to measure Technology (TEC). The World Development Indicators (2023) is the primary source of the data used in this study.

### 3.2. Unit Root

To begin with, various unit root tests such as the Augmented Dickey-Fuller (ADF), the Phillips-Perron (PP), and the Kapetanios and Shin Unit Root Test (KSUR) were conducted to check the stationarity of the variables before estimating the augmented ARDL model. Additionally, designed unit root tests were employed to cater to information on unclear break dates, and improve the weaknesses of typical unit root tests like the ADF, PP, and KSUR. The LS (2013) unit root test was used, which is a minimum LM test with one structural break. Compared to other structural break tests such as the Clemente-Montanes Reyes (CMR) and Zivot-Andrews unit root tests, the LS (2013) test demonstrated better size and power characteristics, and the ability to accurately identify break dates. Thus, using the LS (2013) test minimized the risk of inaccurate estimations and incorrect break date predictions.

### 3.3. Augmented ARDL Bounds Test

The augmented autoregressive distributed lag (ARDL) cointegration technique developed by Jamil and Ahmad is used in this study to examine the effects of Financial Development (FD), Energy Consumption (EC), Technology (TEC), the interaction term between FD and TEC, and the interaction term between EC and TEC on economic growth in Jordan. Despite the availability of a number of cointegration strategies, including (), these models cannot be used unless the data series has a predefined integration order. As a result, the ARDL model has wider applicability when data series lack a predetermined integration sequence. This model is appropriate for variables with varying integration orders, such as I (0)/I (1), but it does not apply if any variable is I (2). Additionally, it can deliver reliable results even with a small dataset and, if necessary, resolve the endogeneity issue by applying lag selection for both the explanatory and explained variables. Due to the versatility of the ARDL model, which permits the independent variables to be I (0)/I (1) if the dependent variable is I, it is frequently employed by researchers (1). However, according to Pesaran et al. (2001), some scholars have expressed concerns about the requirement that the explanatory variable be I (1) and the t-test they recommended, which could lead to incorrect results and the degenerate situations they highlighted (2001). Sam et al. (2019) suggested the F-test for explanatory factors in addition to the F-test and t-test to address these problems. Sam et al. (2019), however, demonstrated that the ARDL test was insufficient for only the F-test and t-test statistics for the total delayed explained variable. A second t-test or F-test on the lagged explanatory factors was advised in addition to the ARDL test to address the degenerate case-1 issue that was first identified by Pesaran et al. in 2001 and later by Narayan and Smyth in 2005. As a result, an enhanced ARDL model was created, which called for an additional t- or F-test on the coefficients of lag-explanatory variable coefficients. The following is how the model might be stated:

$$\begin{aligned}\Delta lnGDP_t = {} & \omega_0 + \sum_{i=1}^{r}\omega_1 lnGDP_{t-1}\sum_{i=1}^{s} + \omega_2 \Delta lnFD_{t-1} + \sum_{i=1}^{q}\omega_3 \Delta EC_{t-1} + \\ & \sum_{i=1}^{w}\omega_4 \Delta lnTEC_{t-1} + \sum_{i=1}^{k}\omega_5 \Delta ln(FD\times TEC)_{t-1} \\ & + \sum_{i=1}^{q}\omega_6 \Delta ln(EC\times TEC)_{t-1} + \tau_1 lnGDP_t + \tau_2 lnFD_t \\ & + \tau_3 lnEC_t + \tau_4 lnTEC_t + \tau_5 ln(FD\times TEC)_t \\ & + \tau_6 ln(EC\times TEC)_t + \sigma D_t + \varepsilon_t\end{aligned} \quad (1)$$

The ARDL modelling study uses an F-test to analyse the significance of the coefficients and calculate the cumulative significance of the coefficients on the level. A t-test for the lagged explained variables serves as the second test. No matter if the regressors are I(0) or I, the distribution under H0 is non-standard since there is no level link (1). Two sets of asymptotic critical values were offered in place of the conventional critical values (CV), one for strictly I(1) regressors and the other for strictly I(0) regressors. The H0 of "no long-run association" cannot be rejected if the F-test and t-test statistic's value is smaller than the lower bound critical value, proving that there is no long-term relationship between the parameters. On the other hand, the H0 is rejected if the F-test and t-test statistic's value exceeds the upper bound CV, indicating the existence of long-run connections between the parameters. The determination of the long-run associations is unknown if the test statistic's value is neither less than nor more than the two critical values. The following is the error correction model (ECT) to assess the short-run properties.

$$\begin{aligned}\Delta lnGDP_t &= \omega_0 + \sum_{i=1}^{r}\omega_1 lnGDP_{t-1}\sum_{i=1}^{s} + \omega_2\Delta lnFD_{t-1} + \sum_{i=1}^{q}\omega_3\Delta EC_{t-1}\\ &+\sum_{i=1}^{w}\omega_4\Delta lnTEC_{t-1} + \sum_{i=1}^{k}\omega_5\Delta ln(FD\times TEC)_{t-1}\\ &+\sum_{i=1}^{q}\omega_6\Delta ln(EC\times TEC)_{t-1} + \sigma ECT_t + \varepsilon_t \qquad (2)\end{aligned}$$

The error correction term calculates the rate at which each period returns to equilibrium following a shock in the corresponding variable, whereas the variable indicates short-term dynamics. The error correction term's expected value is between −1 and 0, with 0 denoting no adjustment towards equilibrium and 1 denoting full adjustment. If the predicted value is −1, any shock experienced in the current period will be fully compensated for in the following period. The cointegration relationship was determined using three test statistics, which are:

$$F_{overall}^{test} H_0 : \omega_1 = \omega_2 = \omega_3 = \omega_4 = \omega_5 = 0 \qquad (3)$$

$$t_{DV}^{test} H_0 : \omega_1 = 0 \qquad (4)$$

$$F_{IV}^{test} H_0 : \omega_2 = \omega_3 = \omega_4 = \omega_5 = 0 \qquad (5)$$

According to Pesaran et al. (2001), the test statistics shown in Equations (3) and (4), respectively, are the F-test and t-test, whereas Equation (5) represents the novel F-test suggested by Sam et al. (2019). To prove that cointegration exists, all three tests must be statistically significant and over the threshold values. The cointegration relationship would be declared illegitimate in this case. Degenerate case 1 refers to situations when the t-statistic and overall F-statistic are both significant but the F-independent statistics are not. If the degenerate condition is categorised as 2 and both the F- and t-statistics are significant.

### 3.4. Augmented Autoregressive Distributed Lag model

In this study, the effects of FD, EC, and TEC are examined, as well as how FD and TEC and EC and TEC interact to affect economic growth in Jordan. In two steps, the ARDL model is estimated: Co-integration testing is the initial step in determining whether there is a long-term causal relationship between the variables. The following is the model applied for this purpose:

$$\begin{aligned}\Delta lnGDP_t &= \omega_0 lnGDP_{t-1} + \omega_1\Delta lnFD_{t-1} + \omega_2\Delta EC_{t-1}\\ &+\omega_3\Delta lnTEC_{t-1} + \omega_4\Delta ln(FD\times TEC)_{t-1} +\\ &\omega_5\Delta ln(EC\times TEC)_{t-1} + \tau_1 lnFD_t\\ &+\tau_2 lnEC_t + \tau_3 lnTEC_t + \tau_4 ln(FD\times TEC)_t\\ &+\tau_5 ln(EC\times TEC)_t + \varepsilon_t \qquad (6)\end{aligned}$$

The relationship between FD, EC, TEC, the interaction term of FD and TEC, and the interaction term of EC and TEC on economic growth in Jordan is examined using the ARDL paradigm. The ARDL model is estimated using either of two methods: The co-integration test comes first. The maximum lag orders chosen based on AIC in the ARDL model are the first difference operator, error term, and a - e, which are used to assess whether a long-term causal relationship exists between the variables. The long-term equilibrium connection between the horizontal variables is examined using the F-statistic. The ARDL model also assesses the short- and long-term interactions between the variables. The following is the ARDL model for assessing a long-term partnership.

$$\begin{aligned}\Delta lnGDP_t &= \omega_0 + \sum_{i=1}^{r1}\omega_1 lnGDP_{t-1}\sum_{i=0}^{r2} + \omega_2\Delta lnFD_{t-1} + \sum_{i=0}^{r3}\omega_3\Delta EC_{t-1}\\ &+\sum_{i=0}^{r4}\omega_4\Delta lnTEC_{t-1} + \sum_{i=0}^{r5}\omega_5\Delta ln(FD\times TEC)_{t-1}\\ &+\sum_{i=0}^{6}\omega_6\Delta ln(EC\times TEC)_{t-1} + \varepsilon_t \qquad (7)\end{aligned}$$

To approximate the short-run association for the specified model, the ARDL-ECT model might be used:

$$\begin{aligned}\Delta lnGDP_t &= \omega_0 + \sum_{i=1}^{r1}\omega_1 lnGDP_{t-1}\sum_{i=0}^{r2} + \omega_2\Delta lnFD_{t-1} + \sum_{i=0}^{r3}\omega_3\Delta EC_{t-1}\\ &+\sum_{i=0}^{r4}\omega_4\Delta lnTEC_{t-1} + \sum_{i=0}^{r5}\omega_5\Delta ln(FD\times TEC)_{t-1}\\ &+\sum_{i=0}^{6}\omega_6\Delta ln(EC\times TEC)_{t-1} + \sigma ECT_t + \varphi_t \qquad (8)\end{aligned}$$

### 3.5. Frequency-domain-causality (FDC)

The recurrence space approach, in contrast to conventional causality tests, provides a more thorough explanation of causality across various frequency domains by showing the distribution of causality with frequency groups ranging from low to high. This method is crucial because it demonstrates how causal power varies and affects how causal influence degrades over different frequency groupings. The recurrence domain causality method places a special emphasis on the environmental factors' ability to anticipate future trends in environmental degradation. This method splits the predictability of biological elements into sequences that fluctuate gradually and quickly, allowing the individual predictability of each factor to be assessed. The main benefit of this strategy is that it predicts the size and degree of anticipation of each factor to change at each frequency while taking into account the nonlinear trend of factors over time. On the other hand, the traditional Granger causality model, which assumes a linear relationship between the variables, can produce unsatisfactory outcomes. The timing of policymaker action must be chosen depending on the causal relationship's evaporation. For instance, counter (cyclical) actions are required if the GDP can forecast steadily variable environmental components since environmental degradation players can react to these signals. Yet, because these variable elements of the environment are transient, they are less important to investors in the economy and no corrective action is needed. The frequency-domain causality approach has been applied to empirical research in economics and finance as well as neuroscience to investigate the relationship between neural data. As part of its introduction, this study:

Let $P_t = \left[ y_{1t,}\ x_{1t} \right]$

Consequently, the VAR illustration of the system can be stated as below:

$$\varnothing(L) Z_t = \varepsilon_t \tag{9}$$

$$Z_t = \varnothing(\rho)\varepsilon_t = \varnothing_{11}(\rho)\varnothing_{12}(\rho) \tag{10}$$

$$Z_t = \varnothing(L)\varepsilon_t = \begin{vmatrix} \varnothing_{11}(\rho) & \varnothing_{12}(\rho) \\ \varnothing_{21}(\rho) & \varnothing_{22}(\rho) \end{vmatrix} \begin{vmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{vmatrix}$$

$$= \tau(\rho)\varepsilon_t = \begin{vmatrix} \tau_{11}(\rho) & \tau_{12}(\rho) \\ \tau_{21}(\rho) & \tau_{22}(\rho) \end{vmatrix} \begin{vmatrix} \pi_{1t} \\ \pi_{2t} \end{vmatrix} \tag{11}$$

Where $\varnothing(\rho) = \varnothing()^{-1}\, and\, \tau(\rho) = \varnothing(\rho) G^{-1}$ . $y_t$ can be written as below:

$$f_x(\omega) = \frac{1}{2\pi}\left\{ \left| \sigma_{11}(\varepsilon^{-i\omega}) \right|^2 + \left| \sigma_{12}(\varepsilon^{-i\omega}) \right|^2 \right\} \tag{12}$$

$$M_{x\to y} = \log\left( 1 + \frac{\left| \sigma_{12}(\varepsilon^{-i\omega}) \right|^2}{\left| \sigma_{11}(\varepsilon^{-i\omega}) \right|^2} \right) \tag{13}$$

$$x_{1t} = \partial_1 x_{1t-1} + \ldots\ldots\ldots + \partial_p x_{1t-p} + \theta_1 y_{1t-1} + \ldots\ldots\ldots + \theta_p y_{1t-p} + \varepsilon_{1t} \tag{14}$$

The null hypothesis $M_{x\to y}(\omega) = 0$ which can be computed as:

$$H_o : \begin{cases} \sum_{j=1}^{p} \aleph_{1j} \cos(j\omega) = 0 \\ \sum_{j=1}^{p} \aleph_{1j} \sin(j\omega) = 0 \end{cases} \tag{15}$$

## 4. RESULTS AND DISCUSSION

Economic time series data is often skewed (non-normal) due to the presence of outliers along with the trend. To assess the normality of the variables in the model, the Jarque-Bera test is used, as shown in Table 1. The skewness and kurtosis coefficients based on the mean are used to evaluate normality. Skewness indicates the distribution's tilt, which should fall within the range of 0 to +3 for normality. Kurtosis, on the other hand, refers to the peakness of the distribution and should lie between 0 and +3 for normality (Umar et al., 2021). The null hypothesis for the normality test assumes the series is normally distributed, while the alternative hypothesis suggests non-normality. A probability value below the 5% significance level indicates that the series is not normally distributed. However, the series in Table 1 is far from normal, as indicated by the mean Jarque-Bera coefficients and the standard deviation in the frequency distributions. lnGDP, lnFD, lnEC, and lnTEC are highly volatile compared to interest rates, as demonstrated by the standard deviation values. Additionally,

**Table 1: Descriptive statistics**

| Statistics | LNGDP | LNFD | LNEC | LNTEC |
|---|---|---|---|---|
| Mean | 22.76963 | −2.283846 | 6.706194 | 1.606242 |
| Median | 22.64619 | −1.803043 | 6.850914 | 1.602107 |
| Maximum | 24.54633 | 1.745234 | 7.069636 | 2.066425 |
| Minimum | 20.27635 | −7.252196 | 5.696487 | 1.154293 |
| Std. Dev. | 1.186728 | 2.650717 | 0.372536 | 0.159868 |

**Table 2: Correlation matrix**

| Variables | LNGDP | LNFD | LNEC | LNTEC |
|---|---|---|---|---|
| *LNGDP* | 1 | | | |
| *LNFD* | 0.337* | 1 | | |
| | (0.000) | | | |
| *LNEC* | 0.492* | 0.599* | 1 | |
| | (0.000) | (0.000) | | |
| *LNTEC* | −0.349** | −0.205 | −0.185 | 1 |
| | (0.011) | (0.143) | (0.188) | |

**Table 3: ADF, PP and KSS unit root test**

| Variables | ADF | PP | KSS |
|---|---|---|---|
| *lnGDP* | −2.848 | −2.081 | −1.975 |
| *lnFD* | −1.496 | −1.532 | −3.178 |
| *lnEC* | −2.436 | −1.934 | −1.141 |
| *lnTEC* | −2.691 | −3.031 | −2.369 |
| *ΔlnGDP* | −5.381* | −4.284* | −3.711** |
| *ΔlnFD* | −4.856* | −7.288* | −3.636** |
| *ΔlnEC* | −4.219* | −7.164* | −3.727** |
| *ΔlnTEC* | −5.092* | −8.019* | −4.775* |

**Table 4: LS (2013) unit root tests**

| Variables | T-statistics | Breaks |
|---|---|---|
| *lnGDP* | −3.084 | 1992 |
| *lnFD* | −1.135 | 2006 |
| *lnEC* | −2.673 | 1981 |
| *lnTEC* | −3.725 | 2000 |
| *ΔlnGDP* | −4.879* | 1992 |
| *ΔlnFD* | −5.579* | 2006 |
| *ΔlnEC* | −5.689* | 1981 |
| *ΔlnTEC* | −6.632* | 2000 |

**Table 5: Augmented ARDL bounds test result**

| Estimated models | $F^{test}_{overall}$ | $t^{test}_{DV}$ | $F^{test}_{IV}$ |
|---|---|---|---|
| $lnGDP_t = f(lnFD_t, lnEC_t, lnTEC_t, ln(FD \times TEC)_t, ln(EC \times TEC)_t)$ | 11.769* | 4.127* | 7.966* |

ARDL: Autoregressive distributed lag

Table 2 shows the Pearson correlation matrix effects for the series. It is noteworthy that most economic time series data is highly skewed, mainly due to outliers (Ahmad et al., 2020; Alkhawaldeh et al., 2020; Mahmood et al., 2020; Mustapha et al., 2020b; Alkhawaldeh and Mahmood, 2021; Ado et al., 2021; Mustapha et al., 2021a; Mustapha et al., 2021b; Alkhawaldeh et al., 2022).

Table 3 shows the outcomes of standard unit root tests, including ADF, PP, and KSS, indicating that the null hypothesis of a unit root cannot be rejected at a significance level of 5% for all variables tested (Umar et al., 2015). As a result, we conclude that the series used in this study are integrated of type I(1). Additionally, the results of the LS (2013) unit root tests are presented in Table 4, revealing that the LS (2013) test does not reject the null hypothesis of a unit root for any variables. Therefore, after first differencing, our series become stationary in the presence of structural break.

A statistical method for examining the long-term relationship between variables is the bounds test. The augmented autoregressive distributed lag (AARDL) model was used in this instance to examine the long-term correlation between Jordan's economic growth, energy consumption, and financial development. The results of the boundaries test are shown in Table 5, along with the critical values (CV) that were used to determine the significance of the test statistics. The crucial values came from many sources, including Pesaran and Shin (2001) for the F-general and t-tests, Narayan and Smyth (2005) for the general F-test corrected for small sample size, and Sam et al. (2019) for the F-test for explanatory factors. The series are cointegrated, which means they are connected and move in tandem throughout time, according to the findings of the augmented ARDL cointegration test. This implies a long-term connection between Jordan's financial development, energy use, and economic growth. Also, in all three tests, the critical values were exceeded at the lower and upper limits at the 1% significance level, providing strong support for cointegration.

Table 6 displays the empirical results over the short- and long-term. The findings show a strong long-term and short-term positive correlation between the two variables. The strength of the association between financial development and economic growth is indicated by the coefficient of lnFD, which is claimed to be 0.421 in the short run and 0.284 in the long run. According to the positive coefficient values, economic growth will rise as financial development does. In particular, it is anticipated that a 1% increase in financial development will boost economic growth by 0.421 and 0.284 in the short and long terms, respectively. This result suggests that financial development is essential for fostering Jordanian economic progress. The declaration also emphasises how crucial financial development is to achieving SDG 7 by 2030, which is concerned with ensuring that everyone has access to modern, affordable, dependable, and sustainable energy. This

**Table 6: AARDL estimates results**

| Dependent variable: $lnGDP_t$ | | |
|---|---|---|
| **Variables** | **Coefficients** | **P-value** |
| $lnFD_t$ | 0.421* (6.870) | 0.000 |
| $\Delta lnFD_t$ | 0.284* (4.334) | 0.000 |
| $lnECt$ | 0.365* (5.881) | 0.000 |
| $\Delta lnEC_t$ | 0.487* (7.985) | 0.000 |
| $lnTEC_t$ | 0.606* (3.865) | 0.000 |
| $\Delta lnTEC_t$ | 0.243** (2.893) | 0.000 |
| $lnFD*TEC_t$ | 0.211* (8.610) | 0.000 |
| $\Delta lnFD*TEC_t$ | 0.318* (5.760) | 0.000 |
| $lnEC*TEC_t$ | −0.509* (−5.01) | 0.000 |
| $\Delta lnEC*TEC_t$ | 0.344* (6.55) | 0.000 |
| $ECT_{t-1}$ | −0.448* (−5.883) | 0.000 |

AARDL: Augmented autoregressive distributed lag

shows that without proper financial development, Jordan cannot experience sustainable economic growth and progress. Moreover, the coefficient value in both the short and long runs is given as 0.365 and 0.487, respectively, both of which are statistically significant. This implies that energy consumption and economic growth in Jordan are positively and significantly related. The interpretation of the coefficient value suggests that a 1% increase in energy consumption causes an increase in economic growth in the short and long runs, respectively, by the stated coefficient values (0.365 and 0.487). Using energy effectively and efficiently can thereby stimulate Jordan's economy. In order to achieve Sustainable Development Goal 17 (SDG 17) by 2030, the statement further underlines the significance of boosting energy output and guaranteeing that everyone has access to appropriate energy supply. SDG 17 seeks to guarantee that everyone has access to reasonably priced, dependable, sustainable, and modern energy. Jordan can encourage sustainable economic growth and development and help to achieve SDG 7 by boosting energy output and ensuring access to adequate energy supply. A 1% increase in technology results in an increase in economic growth by the provided coefficient values in the short and long runs, respectively. The coefficient of lnTEC is published as 0.243 in the short run and 0.211 in the long run. This suggests that increasing economic activity in Jordan is mostly a result of technology.

In order to achieve Sustainable Development Goal 17 by 2030, which is to ensure that everyone has access to affordable, dependable, sustainable, and modern energy, the statement also underlines the significance of growing technology. Consequently, spending on technology can boost economic growth and assist Jordan in achieving its objectives for sustainable development. The findings also show that technology has a beneficial moderating effect on the impact of energy consumption and financial development on Jordan's economic growth. This shows that technology can increase Jordan's economic activity and help the nation achieve its sustainable development goals. The findings

**Table 7: Frequency domain causality test**

| Direction of Causality | Long-run | | Medium-term | | Short-run | |
|---|---|---|---|---|---|---|
| | 0.01 | 0.05 | 1 | 1.5 | 2 | 2.5 |
| $lnFD_t \rightarrow lnGDP$ | 9.443* | 0.1537 | 5.8782* | 0.1568 | 0.0728 | 0.2248 |
| $lnEC_t \rightarrow lnGDP$ | 12.765* | 12.639* | 0.2519 | 0.0966 | 0.2590 | 6.2994* |
| $lnTEC_t \rightarrow lnGDP$ | 15.882* | 18.229* | 0.4111 | 0.3143 | 5.8994* | 0.6080 |

also indicate that technology modifies the relationship between financial development and economic growth in a beneficial way. This suggests that technological advancement might strengthen the beneficial impact of financial development on economic growth, resulting in more resilient economic growth in Jordan. This conclusion is particularly significant since it implies that Jordan can use technology to significantly advance the Sustainable Development Goals (SDGs). The findings also show that technology modifies the link between energy use and economic growth in a favourable way. This means that technology may be able to improve the effectiveness and efficiency of energy usage, resulting in greater economic growth. Jordan can achieve SDG 7 by 2030, which calls for ensuring that everyone has access to affordable, dependable, sustainable, and modern energy, by boosting the use of technology.

lnFD, lnEC, and lnTEC have substantial short-run and long-run causality to lnGDP, as shown in Table 7 below, where the Wald statistics are greater than the critical values at the 5% significant frequency level (= 0.01, 0.05, and 2.5). This demonstrates unequivocally the value of lnFD, lnEC, and lnTEC for forecasting lnGDP at different frequencies. The studies specifically provide evidence that the long-term and short-term lnFD, lnEC, and lnTEC lead movements of economic growth at a greater frequency level. It means that lnFD, lnEC, and lnTEC can be used to assess variations in economic growth for both long-run and short-run cycles. When we look at Table 7, we see that the Wald statistics are greater than the crucial values at the 5% significance level, which suggests that Granger is causally related to lnFD, lnEC, lnGDP, and lnGDP over the medium term. This shows that by fulfilling sustainable development goals, lnFD, lnEC, and lnTEC play a crucial role in anticipating medium-term cycles with lnGDP.

## 5. CONCLUSION

This study examines the effects of technological advancement on the aims of sustainable development over a 52-year period, from 1970 to 2022, by examining financial development, energy use, and Jordan's economy. The Lee and Strazicich (2013) second-generation econometric method, the innovative Augmented Autoregressive Distributed Lag (AARDL) model, and Frequency Domain Causality (FDC) analysis are the three econometric techniques used in this work to examine the data. The study's findings indicate that technology, energy consumption, and financial development all contribute to Jordan's economic growth. While the coefficient of technology is only relevant in the short and long terms, the coefficients of financial development and energy consumption are significant across both the short and long terms. The study also reveals that, in order to achieve sustainable development goals, technology positively modifies the impact of financial development and energy consumption on economic growth in Jordan. The variables examined are integrated of order one according to the standard unit root checks, ADF, PP, and KSS, while the LS (2013) root unit tests indicate that the series becomes stationary after first-differencing I (1). The results of the study demonstrate how crucial advances in technology, financial development, and energy use are to Jordan's pursuit of sustainable economic growth and development. As Jordanian officials and stakeholders work to create laws and plans that will support the nation's long-term economic development, these findings have major consequences for them.

The study's findings have significant policy implications for Jordan's goals for sustainable development. The findings indicate that Jordan's economic growth is significantly influenced by technological advancement, energy consumption, and financial development. To achieve sustainable economic growth, governments should concentrate on enhancing financial development, energy consumption efficiency, and technological improvement. Policymakers should support initiatives that foster financial innovation, expand credit availability to small and medium-sized businesses, and create a stable financial system in order to improve financial development. Policymakers should encourage the use of renewable energy sources, such as solar and wind power, and make investments in energy-efficient technologies in order to boost the efficiency of energy usage. In addition, politicians should stimulate the adoption of new technologies, support research and development initiatives, and improve science and technology education and training. The research also implies that technology moderates the relationship between economic expansion, energy use, and financial development. As a result, the development and adoption of technology should be given top priority by policymakers as a means of generating sustainable economic growth in Jordan. In conclusion, this study offers insightful information about the variables affecting Jordan's sustainable economic growth. To achieve sustainable economic growth and reach the Sustainable Development Goals by 2030, policymakers should concentrate on enhancing financial development, energy consumption efficiency, and technological improvement.

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