“The impact of government expenditure, renewable energy consumption, and CO2 emissions on Lebanese economic sustainability: ARDL approach”

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THE IMPACT OF GOVERNMENT EXPENDITURE, RENEWABLE ENERGY CONSUMPTION, AND CO2 EMISSIONS ON LEBANESE ECONOMIC SUSTAINABILITY: ARDL APPROACH

Abstract

Most of the recent environmental and economic studies focus on the influence of renewable energy consumption and effective government expenditure respecting global climate change in leading sustainable economic growth. The empirical studies showed variation in the relationship between these variables. Based on the Keynesian economic growth framework, this study aims to investigate the impact of government expenditure, renewable energy consumption, and carbon dioxide emissions on the sustainable economic growth of Lebanon. The study used the ordinary least square method to test the short- and long-run relationship between the model variables by employing the Autoregressive Distributed Lag Stationarity estimation. The research data are gathered from the World Development Indicators annually from 1990 to 2022. The empirical findings showed that all variables are stationary at first difference except for carbon dioxide emissions. A long-term relationship between the dependent and independent variables was shown by the model test simulation employing the bound test. The model test for model residuals showed no heteroscedasticity based on the White test. The residuals are normally distributed by applying the Shapiro-Wilk test, and the model is stable with no structural break at the period. According to the study results, government spending has a robust reverse relation with sustainable economic growth and positive significant results for both renewable energy consumption and carbon dioxide emissions. The study findings are consistent with some literature sources and raise attention to monitoring the nature of government spending and boosting green energy sources in an economy.

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INTRODUCTION

Government spending and energy consumption are considered the main factors in economic growth. Economic theories, like Keynesian demand and Big Push theory, focused on the government expenditure increase as a need to improve economic well-being in an economy through the improvement in public goods (Keynes, 1936 cited in Meltzer, 1981). In accordance, the increase in government expenditure, along with the presence of proper energy consumption and moderate carbon dioxide emissions respecting the economy's well-being, is an essential element to study. As per the Solow Growth model, the major factors for economic growth are capital, labor, and technological progress, which are related to energy consumption (Solow, 1956). Nowadays, in line with the United Nations' sustainability goals, green energy is a source of production, enhancing the worldwide energy usage transformation as a basis for economic sustainability (Osabohien

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et al., 2018). Emergent economies are experiencing higher environmental deterioration due to heavy reliance on fossil fuels for energy consumption; thus, their economic sustainability is a matter of focus.

Lebanon, as an emergent economy with a complicated economic situation in the Middle East region, faces huge government spending and low green energy usage. However, the Lebanese economic and financial crisis, along with the COVID-19 lockdown, made this mission harder. Before 2019, electricity production was low due to fuel unavailability, which deepened the crisis. Since then, the Lebanese economy has been experiencing redundant growth without development, as most of the government expenditures have been directed outward to governmental investments or development. In addition, the Lebanese weakness in decreasing the pollution as proxied in CO2 emissions would also affect the economic well-being (IMF, 2023).

In the Lebanese economy, the government expenditure on non-green energy production is very high. One of its main reasons is the budget deficit and, thus, the public debt, which is a weakness in the investment in research and development (IMF, 2023). Accordingly, non-green energy consumption, along with high environmental degradation and high government expenditure, affect economic sustainability. Emphasizing the relationship between government spending and renewable energy consumption is crucial for the economic sustainability of Lebanon. Green energy consumption in Lebanon has recently become highly important as part of local crisis management. Renewable energy consumption in Lebanon basically depends on solar system development, which has led, in turn, to the development of other sources of green energy. This system was formed due to the high importance of private initiative in the development of solar energy. The Lebanese green energy sector is underdeveloped despite the spread of solar energy throughout the country (IMF, 2023). The CO2 emissions as a proxy for air pollution showed a significant decrease in Lebanon during the COVID-19 pandemic with an increasing trend over the years, which could affect the Lebanese economic well-being.

1. LITERATURE REVIEW AND HYPOTHESES

From a theoretical aspect, the economic growth theories as presented by Keynes show the public expenditure as exogenous factor in generating sustainable development (Keynes, 1936 cited in Meltzer, 1981). The positive contribution of government expenditure to sustainable development led to the conclusion that the essential reason to push the aggregate demand is government expenditure. In this context, Solow (1956) highlighted that capital, labor, and technological progress are the major factors for economic growth, which are related to energy consumption as a major source of production.

In the literature, the relationship between government expenditure, energy consumption, CO2 emission, and economic growth showed an empirical variation. This study's theoretical framework is derived from Keynesian theory on economic growth (Keynes, 1936 cited in Meltzer, 1981). Keynes (1936) argued that government spending raises output growth. There is a causality variation between government expenditure and economic growth relationship (Loizides & Vamvoukas, 2005; Jiranyakul & Brahmasrene, 2007; Liu et al., 2008). However, most of the empirical studies showed a positive impact of government spending on economic growth (Danladi et al., 2015; Chiawa et al., 2012; Nurlina, 2015). Conversely, some studies showed a negative impact of government expenditure on economic growth (Connolly & Li, 2016). On the other hand, the effect of economic growth and government expenditure on green energy showed another empirical variation. Zhang et al. (2021) investigated the relationship between green economy growth, public spending on R&D, and energy efficiency for the period between 2008 and 2021. They concluded that it is essential to foster public expenditure on research and development and human capital to sustain a green economy through technology-focused manufacturing behavior, yielding diverse effects.

Numerous research found a significant role of energy consumption in contributing to environmental degradation (Aqeel & Butt, 2001; Pao &

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Tsai, 2010; Acaravci & Ozturk, 2010; P. Narayan & S. Narayan, 2010; Alam et al., 2012; Saboori & Sulaiman, 2013). Another wave of studies, for example, Chen et al. (2007), Ismail and Yunus (2012), Narayan et al. (2016), and Aller et al. (2021), affirmed the existence of a causal relationship between GDP growth and carbon emissions.

Variations in results are found in the relationship between energy consumption, carbon emission, and economic growth. Li et al. (2011) investigated the long-term co-integration relationship between energy use and real GDP per capita for Chinese provinces. They found a positive long-run co-integrated relationship. Begum et al. (2015) looked at how energy consumption, population growth, and GDP growth dynamically affected CO2 emissions. The results show that both per capita GDP and per capita energy use have a positive impact on per capita CO2 emissions in Malaysia. For twelve Middle East and North Africa (MENA) nations, Arouri et al. (2012) looked at the relation between real GDP as a proxy for economic growth, carbon dioxide emissions, and energy consumption, using bootstrap and co-integration panel test techniques. The results showed that energy consumption has a long-term significant positive impact on carbon dioxide emissions. Economic growth and CO2 emissions have a positive and strong correlation, as demonstrated by Raihan et al. (2022). On the other hand, Soytas et al. (2007) examined the effect of energy output and consumption on carbon emissions in the United States. They observed positive effects of only consuming energy on long-term CO2 emissions. Chen et al. (2016) investigated the relationships between energy consumption, CO2 emissions, and economic growth for 188 nations worldwide between 1993 and 2010. They found that, in every country, the relationship between consumption of energy and CO2 emissions was unidirectional, with only developing countries experiencing a negative relationship between economic growth and consumption of energy. However, Chen et al. (2020), using a threshold model across a sample of 103 countries, investigated the causal relationship between economic growth and renewable energy. The findings demonstrated that the use of renewable energy boosts economic expansion only after reaching a particular level of use and a negative impact below this threshold.

The relationship between government spending, renewable energy consumption, carbon dioxide emissions, and economic growth in Lebanon has not been heavily studied. Lebanon relies heavily on imported oil products to fulfill almost all its energy requirements because of the absence of conventional fossil fuel sources and the underutilization of available renewable energy resources. Hence, it is imperative for the government to prioritize exploration for these resources. Additionally, a thorough assessment of renewable energy potential highlights significant opportunities in solar and wind energy in Lebanon (Ibrahim et al., 2013). Investing in renewable energy is crucial for the economic and social prosperity of countries like Lebanon. Lebanon faces a significant energy bill due to high emissions resulting from inefficient conventional methods used in the country (Kinab & Elkhoury, 2012). Researching the relationship between energy consumption and economic growth in Lebanon from 1980 to 2009, Dagher and Yacoubian (2012) discovered a restricted long-term relationship and a bidirectional one in the short term. In studying the economic growth and renewable energy consumption in Lebanon for the period from 1990 to 2012, Taher (2017) discovered that renewable energy consumption boosted economic expansion. In another study, Taher (2019) examined the impact of climate change dimensions on economic growth in Lebanon. The results showed that two climate change variables affect economic growth negatively, whereas two other factors favorably affect Lebanon's economic expansion.

According to the literature review and the theoretical framework of Keynesians presented, the relationship between government expenditure, carbon dioxide emissions, energy consumption, and economic growth sustainability varied in results and from one economy or group of economies to another. In the same vein, empirical studies on the Lebanese economy showed variation but did not cover all study variables together.

This study aims to explore the impact of government expenditure, renewable energy consumption, and carbon dioxide emissions on the sustainable economic growth of Lebanon. Therefore, a conceptual model is formulated in Figure 1, and the hypotheses are elaborated on as follows:

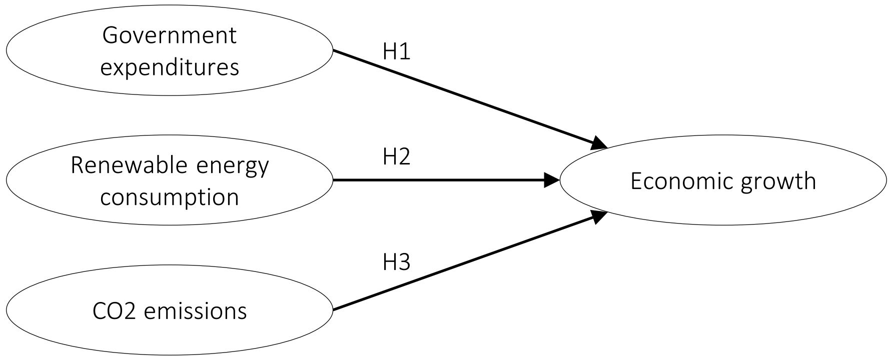

Figure 1. Conceptual model

H1: Government expenditure negatively influences economic growth.

H2: Renewable energy consumption boosts economic growth.

H3: CO2 emissions negatively influence economic growth.

2. METHOD

The Keynesian theory of economic growth highlighted the importance of government expenditure as an accelerator of sustainable economic growth (Keynes, 1936 cited in Meltzer, 1981). The Keynesian model mentioned that government expenditure expansion increases economic growth sustainability. This paper considers the Cobb-Douglas production function as a theoretical framework, which is adapted by the Pedroni model where the energy is essential in economic growth as Y = f(K, L, S), where S is a productive energy (Pedroni, 2004). The study model is as follows:

$$Y = f(G\exp,\ REC,\ CO2), \tag{1}$$

where Y is GDP per capita, *Gexp* is government expenditure; *f* is a functional relationship; *REC* is renewable energy consumption, *CO2* is carbon dioxide. The explicit version of the model function is as follows:

$$Y = \beta 0 \cdot G\exp \beta 1 \cdot REC\beta 2 \cdot CO2\beta 3 \cdot \mu, \tag{2}$$

whereas μ is the stochastic disturbance term.

In (2), the model is expressed in a non-linear form, thus in (3), the model is linearized to enable estimation as follows:

$$Yt = \beta 0 + \beta 1 G\exp_t + \beta 2 REC_t + \beta 3 CO2_t \cdot \mu_t. \tag{3}$$

The natural logarithm for some variables is applied except for *REC* and *Gexp*, and assuming linearity among the variables, the model equation gives:

$$LnY_t = \beta 0 + \beta 1 Gexp_t + \beta 2 REC_t + \beta 3 LnCO2_t + \varepsilon_t. \tag{4}$$

where Y is the real GDP per capita (constant 2015 USD); *REC* is renewable energy consumption estimated as a percentage of total final energy consumption; *CO2* is the carbon dioxide emissions measured as CO2 emissions (kt).

In this study, an ARDL test is employed as an estimation technique, as presented by Pesaran and Shin (1995). They presented an approach to cointegrate a bound procedure for long-run relationships, notably when the existence of one cointegrating vector (Johansen integration) cannot be applied, disregarding the level of stationarity; this approach is called Autoregressive Distributed Lag (ARDL). ARDL gives a more realistic and efficient estimation. In addition, ARDL parameterization results give the model variables short and long-run relationship specifications.

3. RESULTS

The model descriptive results indicate that Lebanese economic growth is increasing despite the slight decline during the 2019 economic and financial crises (Figure 2a). However, the major issue in the Lebanese economy is the consecutive increase of government expenditure on the consumption side, which puts high pressure on the

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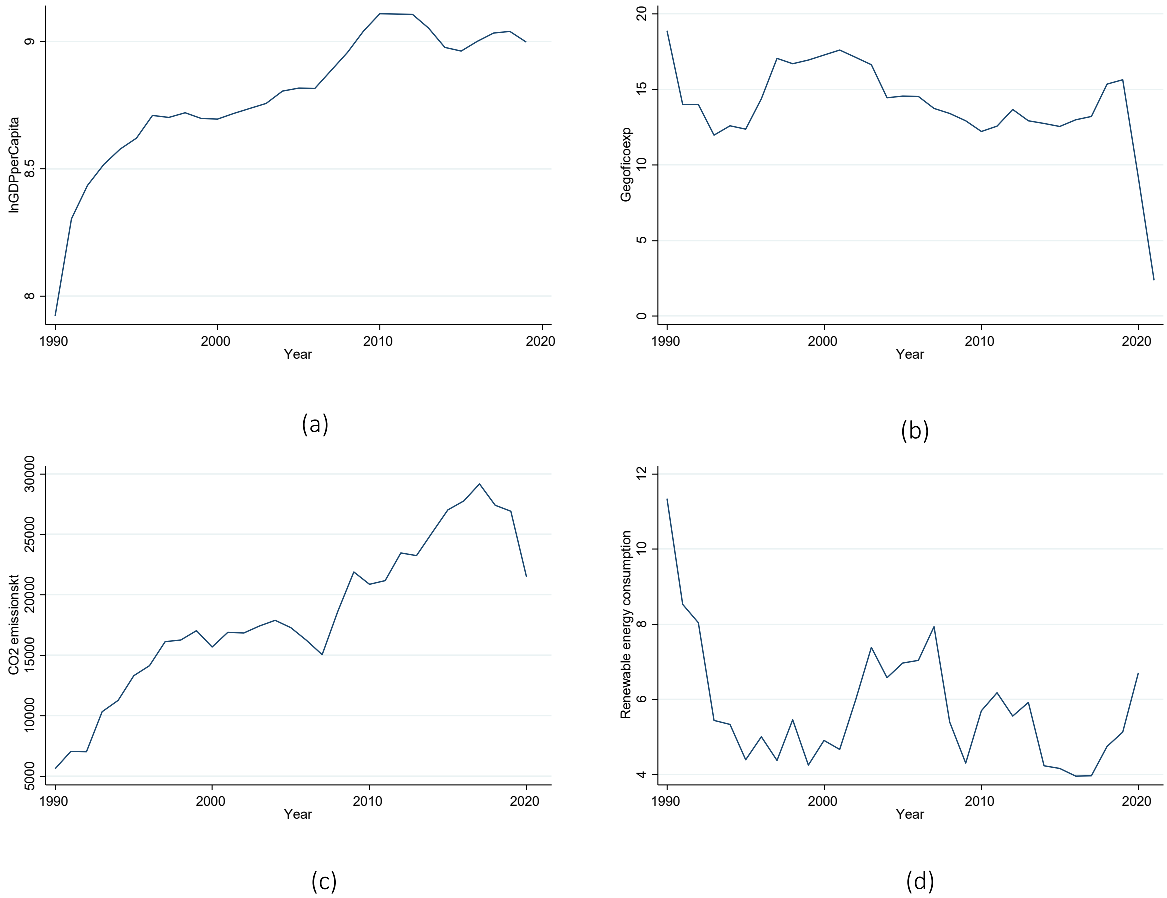

Figure 2. Variation of variables with time (Gdp per capita, General government final consumption expenditure, CO2 emissions in kt, Renewable energy consumption)

public deficit (Figure 2b). The CO2 emissions as a proxy for air pollution in Lebanon are increasing with a slight decrease after COVID-19 and the Lebanese 2019 financial crisis (Figure 2c). The Lebanese green energy sources showed a variation with a clear increase after the recent financial crisis (Figure 2d).

Model analysis via the ordinary least square starts by testing the model stationarity. According to Yule (1926), if the series has a unit root, it is non-stationery. In addition, unit root test helps in determining the model variables' integration order. On testing the stationarity of this model series, one of the most known and efficient unit root test used is Augmented Dickey-Fuller test (ADF).

The results in Table 1 show that the model variables are stationary at the first difference I (1) except for the ln CO2 emissions, which were integrated at level I (0) at the significance level of 5%.

Table 1. Unit root tests on the individual series

Variable	Series			Series in first difference		
	Test statistic	Dickey-Fuller critical value (5%)	P-value	Test statistic	Dickey-Fuller critical value (5%)	P-value
Ln GDP per Capita	–2.860	–3.576	0.176	–5.368	–2.986	< 0.001
General government final consumption expenditure (%)	–0.381	–2.983	0.913	–2.990	–2.986	0.049
Renewable energy consumption	–4.295	–2.989	0.005	–	–	–
Ln CO2emissions (kt)	–3.714	–2.986	0.004	–	–	–

According to Stock and Watson, the ARDL models are sensitive to the number of lag orders. This econometric test determines the model with minimal Akaike Information Criterion (AIC) and Schwartz Information Criterion (SBIC) values (Stock & Watson, 1993).

Table 2. Maximum number of lags

Lag	FPE	AIC	HQIC	SBIC
0	0.002707	5.43936	5.49754	5.62967
1	0.000017*	0.380395*	0.6713*	1.33197*
2	0.000036	1.03409	1.55772	2.74692
3	0.000074	1.53681	2.29317	4.0109

Note: * is the optimal lag for FPE, AIC, HQIC & SBIC tests.

Table 2 shows the maximum lag that can be used through the Final Prediction Error (FPE), Akaike Information Criterion (AIC), Hannan-Quinn Information Criterion (HQIC), and Schwartz Information Criterion (SBIC). It considers that the optimal lag is 1 since it represents the minimum values between the other lags (0.000017 for FPE; 0.380395 for AIC; 0.6713 for HQIC; and 1.33197 for SBIC).

Model estimation starts by running the ARDL regression at the optimum distributed lags according to the Akaike and Schwarz information criteria, as shown in Table 1. The second step is to check the long and short-run relationship between variables, as demonstrated in Table 2. In Table 3, the regression shows a significant negative impact of government expenditure and CO2 emissions on economic sustainability in the first lag, while renewable energy consumption showed a positive impact on economic growth sustainability.

In Table 4, ADJ to the ln GDPC showed a negative value (–0.4919071) representing the speed-of-adjustment. This value checks the effectiveness of the dependent variable reaction to the equilibrium relationship deviation in one period or the speed of equilibrium distortion. Consequently, in the second part of Table 4, the long-run coefficients demonstrated that renewable energy consumption and CO2 emissions influence economic sustainability positively, although government spending has a detrimental effect. This outcome supports Taher (2017, 2019), Chen et al. (2020), and Connolly and Li (2016). However, two positive coefficients (0.0226092 and 0.3135946) are reported in the short-run relationship. This means that they are counted for short-run fluctuation, disregarding the long-run equilibrium deviation.

As a co-integration method in testing the model variables long run relationship, ARDL bound test (Pesaran et al., 2001) is applied.

Based on Table 5 results, the *F*-statistic is 9.412, which is larger than 1%, 5%, and 10% (as the *F* critical values). Thus, the test rejects the null hypoth-

Table 3. ARDL regression

ARDL(1,1,1,0) regression						
Sample: 1991–2020	Number of observations					30
	R-squared					0.9489
	Adj R-squared i					0.9356
	Root MSE					0.0532
	F(6, 23)					71.25
Log Likelihood = 49.40159	Prob > F					0.0000
lnGDPperCapita	**Coefficient**	**Std. err.**	**T**	**P > |t|**	**[95% conf. interval]**	
lnGDPC						
L1.	.5080929	.1387899	3.66	0.001	.2209842	.7952016
Gexp						
L0	.011866	.0068063	1.74	0.095	–.002214	.025946
L1.	–.0226092	.0088724	–2.55	0.018	–.0409632	–.0042552
lnCO2						
L0	.5762971	.153084	3.76	0.001	.2596187	.8929755
L1.	–.3135946	.1145447	–2.74	0.012	–.5505483	–.0766409
REC	.0444059	.0130675	3.40	0.002	.0173737	.071438
_cons	1.682128	.5835101	2.88	0.008	.4750459	2.889211

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Table 4. ARDL long-run and short-run results

ARDL(1,1,1,0) regression						
Sample: 1991–2020	Number of observations					30
	R-squared					0.7356
	Adj R-squared					0.6666
Log Likelihood = 49.40159	Root MSE					0.0532
D.lnGDPC	**Coefficient**	**Std. err.**	**T**	**P > | t |**	**[95% conf. interval]**	
ADJ						
lnGDPC						
L1.	–.4919071	.1387899	–3.54	0.002	–.7790158	–.2047984
LR						
Gexp	–.0218399	.0122568	–1.78	0.088	–.0471951	.0035152
lnCO2	.5340491	.093451	5.71	0.000	.340731	.7273673
REC	.0902729	.028792	3.14	0.005	.0307122	.1498336
SR						
Gexp						
D1.	.0226092	.0088724	2.55	0.018	.0042552	.0409632
lnCO2						
D1.	.3135946	.1145447	2.74	0.012	.0766409	.5505483
_cons	1.682128	.5835101	2.88	0.008	.4750459	2.889211

Table 5. Bound test

H0: no level relationship					F	9.412	
Third case					t	–3.544	
Finite sample (three variables, 30 observations, two short-run coefficients)							
F and T tests	**10%**		**5%**		**1%**		**p-value**	
	I (0)	**I (1)**	**I (0)**	**I (1)**	**I (0)**	**I (1)**	**I (0)**	**I (1)**
F	3.006	4.231	3.717	5.128	5.469	7.323	0.000	0.002
T	–2.565	–3.461	–2.933	–3.885	–3.699	–4.760	0.014	0.088

Note: *H0:* no cointegrating equation ($\varphi1 = \varphi2 = 0$); *H1: H0* is not true.

esis (Kripfganz & Schneider, 2020). This indicates that independent and dependent variables have a long-term relationship.

In diagnosing the model, some econometric tests are essential, e.g., checking heteroscedasticity, normality, and model stability.

As a first step in diagnosing the research model, heteroscedasticity is essential in checking if the model residuals are homoscedastic or have a constant variance. Also, this helps detect the existence of the model residuals and independent variables' relationship. White test is a convenient method to check heteroscedasticity, which is based on Chi-Square distribution and is conjunct with other methods (Cameron & Trivedi, 2005).

The chi-square value shown in Table 6 is greater than 0.05 as a critical *p*-value; therefore, the hull hypothesis is rejected. As heteroscedasticity does not exist, the model residuals estimated are randomly distributed.

Table 6. Heteroscedasticity White's test

chi2(27) = 27.72			
Prob >chi2 = 0.4257			
Source	**chi2**	**df**	**p**
Heteroskedasticity	27.72	27	0.4257
Skewness	4.34	6	0.6305
Kurtosis	0.73	1	0.3929
Total	32.79	34	0.5269

Table 7. Normality test

Variable	Obs	W	V	z	Prob > z
resid	30	0.95345	1.479	0.810	0.20901

As part of model diagnosis, a normality test is essential to understand whether the sample is normally distributed and, thus, later to check the model stability. According to the Shapiro-Wilk test for normality, the data are normal if the test value exceeds 0.05 (Shapiro & Wilk, 1965).

According to Table 7, the *p*-value equals 0.209, greater than 0.05. The test results fail to reject the null hypothesis; accordingly, the model residuals are distributed normally.

Structural break tests are meant to determine if there is significant change in the model parameters at a point in time. In other words, *H0* means that there is no break while *H1* means that there is a break. This would help in recognizing the stability of the model.

Based on Table 8, 0.850 < the critical values at 1% and 5% ≥ failed to reject the null hypothesis that the model has no structural break. Therefore, the model is stable.

According to model test results, the dependent and all independent variables (government expenditure, renewable energy consumption, and carbon emissions) have a long-term relationship. This supports (Keynes, 1936 cited in Meltzer, 1981), Liu et al. (2008), Acaravci and Ozturk (2010), P. Narayan and S. Narayan (2010), Alam et al. (2012), Saboori and Sulaiman (2013), Narayan et al. (2020), and Aller et al. (2021). Moreover, the significant positive long-term influence of renewable energy consumption and carbon dioxide emissions on Lebanese economic growth is consistent with the research findings by Li et al. (2011), Arouri et al. (2012), Taher (2017, 2019), and Chen et al. (2020). Thus, the study accepts *H2* and *H3*. Next, the study found a negative influence of government spending on Lebanese economic growth, which is in accordance with Connolly and Li (2016) and Zhang et al. (2021). The study accepts *H1*.

4. DISCUSSION

The empirical studies related to the relationship between government expenditure, green energy usage, and economic growth sustainability showed variations. The results of this study showed that the test variables have a long-term relationship. This finding confirms the basic Keynesian assumptions that government expenditure has a significant positive relationship with economic growth (Keynes, 1936 cited in Meltzer, 1981). However, the study results showed the negative impact of government expenditure on economic growth, which contradicts the Keynesian assumption. These findings affirm Connolly and Li (2016) and Zhang et al. (2021), which could be justified by the weakness in the research and development. According to Zhang et al. (2021), public expenditure on research and development is essential to sustain economic growth.

Furthermore, the research results showed that the relationship between renewable energy consumption and CO2 emission has a positive influence on pushing economic growth. This confirms previous findings (Li et al., 2011; Dagher & Yacoubian, 2012; Begum et al., 2015; Taher, 2017, 2019). Both Li et al. (2011) and Dagher and Yacoubian (2012) found a positive long-run co-integrated relationship between energy use and economic growth for the Chinese provinces and Lebanon, respectively. Taher (2017), studying the Lebanese economy, showed a positive impact of renewable energy consumption on economic growth. Taher (2019) also showed that carbon dioxide emission is one of the climate change variables that has a positive impact on Lebanese economic growth.

Table 8. Cumulative sum test for parameter stability

Sample: 1991–2020		Number of obs = 30		
H0: No structural break				
Classification	Test	Critical value		
Type	Statistics	1%	5%	10%
Recursive	0.6491	1.1430	0.9479	0.8499

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CONCLUSION

This study examined the impact of government expenditure, renewable energy consumption, and carbon dioxide emissions on sustainable economic growth in Lebanon for the period between 1990 and 2022. The econometric test started by checking the stationarity; unit root test results showed that all series are stationary at first difference. By applying the ARDL estimation, the study found a significant negative impact of government expenditure and CO2 emissions on economic sustainability in the first lag; economic sustainability expansion is positively influenced by renewable energy consumption. The long-run coefficients show that renewable energy consumption and CO2 emissions have a substantial positive influence on the expansion of the Lebanese economy, while government expenditure has a negative impact, which supports the literature. However, two positive coefficients are reported in the short-run relationship. This means that they are counted for short-run fluctuation, disregarding the long-run equilibrium deviation.

Based on this study's results, renewable energy sources are vital to improve the sustained economic growth of Lebanon. Despite the positive influence of carbon dioxide emissions on economic growth as an indicator of economic productivity, Lebanese policymakers should focus on encouraging green energy sources for energy consumption as well as improving the regulations related to CO2 emissions for better economic well-being. Third, the negative influence of the Lebanese government's expenditure on economic growth should attract attention to the question of the direction of government expenditure, which is not toward research and development. Accordingly, the study recommends revising the Lebanese government policies in a reduced direction to focus on the public investment in research and development more than the consumption side for long-term sustainability.

AUTHOR CONTRIBUTIONS

Conceptualization: Hanadi Taher.
Formal analysis: Hanadi Taher.
Funding acquisition: Hanadi Taher.
Methodology: Hanadi Taher.
Resources: Hanadi Taher.
Software: Hanadi Taher.
Validation: Hanadi Taher.
Writing – original draft: Hanadi Taher.
Writing – review & editing: Hanadi Taher.

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