Understanding the causality relationship between renewable energy consumption and unemployment rates: The Toda-Yamamoto technique

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Jordan has the potential to lead the efforts toward the expansion of renewable energy projects in the Middle East. Expansion in renewable energy projects means creating green jobs in the energy sector. This paper aims to examine the causal relationships among renewable energy consumption, total unemployment rates, general government final consumption expenditure, and gross fixed capital formation by applying the Toda-Yamamoto causality test. The time series covers the period from 1991 to 2018. The results show that the variables are cointegrated in the long run. Moreover, our results show that unidirectional causality runs from all the variables toward total unemployment rates. On the other hand, causality is not detected between the other variables. It is confirmed that, in the long run, renewable energy can contribute to job creation. In conclusion, it is suggested that both investments and policies should focus on utilising renewable energy projects; it would create more green jobs, especially in the energy sector.

Keywords: Toda-Yamamoto technique, causality test, renewable energy, unemployment, energy policies.

JEL codes: C01, E24, Q01, Q43.

Introduction

Utilising renewable energy became a priority in the previous years, and many countries are working on greening their energy sector. A transition to renewable energy directly reduces CO_2 emissions while achieving the Sustainable Development Goals (SDGs) by 2030. Jordan can lead the efforts toward expanding renewable energy projects in the Middle East. The geographical location and the total number of 330 sunny days, for instance, make the country suitable for utilising solar energy (Qasaimeh et al. 2014).

Jordan introduced the Renewable Energy and Energy Efficiency Law, supplemented by rules and regulations to guide renewable energy projects. Furthermore, Jordan Renewable Energy and Energy Efficiency Fund (JREEEF)

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was established to facilitate the implementation of renewable energy projects and energy efficiency in Jordan. Expansion in renewable energy projects means creating green jobs in the energy sector; this would help the government to achieve its green growth plan while reducing the unemployment rates. In 2020 and after the Covid-19 outbreak, the unemployment rate of the total labour force increased to 19.0% compared to 16.8% in 2019 (World Bank 2021). According to the Ministry of Energy and Mineral Resources, by 2020, the contribution of renewable energy resources to electricity generation was 20%, while 80% came from natural gas consumption. Domestic energy resources contributed only 22% of total electricity generation (Ministry of Energy and Mineral Resources 2020). Until the end of 2019, nearly 26 000 jobs in Jordan were in the renewable energy sector (IRENA 2020): solar photovoltaic technology offers 20 000 jobs, followed by solar/heating technology (4000 jobs) and wind energy (1100 jobs). According to the same report by IRENA, Jordan is one of the top ten countries in terms of employment in the solar heating and cooling sector. By the end of 2020, the number of jobs in Jordan related to the renewable energy sector increased to 37 000.

This paper applies the Toda-Yamamoto causality test to examine the causal relationships among renewable energy consumption, total unemployment rates, general government final consumption expenditure, and gross fixed capital formation.

Literature review

Apergis and Salim (2015) used a sample from 80 countries to study the relationship between renewable energy consumption and unemployment, using a non-linear Granger causality test. The results indicated that renewable energy consumption positively impacts unemployment rates. The results also showed that, on the disaggregated level, in regions such as Latin America and Asia, energy efficiency and the cost of adopting renewable technologies are the main factors affecting job creation in the renewable energy sector.

Using the autoregressive distributed lag model (ARDL), Khobai et al. (2020) studied the short-run and long-run relationship between renewable energy consumption and unemployment rates in South Africa. Their results showed that in the long run, unemployment rates were negatively affected by renewable energy consumption, while in the short run, no relationship was detected.

Saidu Musa and Rabiu (2020) used the Toda-Yamamoto technique to study the causality relationship between renewable energy consumption and Nigeria's unemployment rates from 1991 to 2015. They found that in the long term, bidirectional causality runs from consumption of renewable energy to unemployment, foreign direct investment to consumption of renewable energy, investments to consumption of renewable energy, and private sector credit to investments. In contrast, a unidirectional causality runs from investments to unemployment and private sector credit to unemployment.

Satrovic and Adnan (2020) used the Granger causality test to study the linkage between youth unemployment rates and energy consumption in 34 OECD countries from 1991 to 2015. The findings demonstrated a causal link between energy consumption and youth unemployment rates. The authors suggest that policymakers in the OECD member states should promote energy consumption in the industrial sector. They also suggest that supporting startups can lead to reducing youth unemployment rates.

Yilanci et al. (2020) studied the cointegration relationship between renewable energy consumption and unemployment rates for selected OECD countries. The researchers used the Fourier ADL cointegration test for that purpose. The study revealed mixed results for the selected countries, indicating that unemployment rates are affected positively by renewable energy consumption in Austria, Portugal, and Spain and negatively in Australia, Chile, France, Germany, and Japan.

Azretbergenova et al. (2021) used the panel ARDL test to study the relationship between renewable energy consumption and unemployment rates in 27 countries in the European Union. The findings pointed out that employment rates increase by 0.08% when 1% of the energy produced is renewable. They suggest that investing in the renewables sector can contribute to reducing unemployment rates.

El Moummy et al. (2021) studied the role of renewable energy consumption in reducing unemployment rates in Morocco. They used the Granger causality test for the period 1990 to 2017. The results of the study revealed that renewable energy consumption causes unemployment rates. They argued that investments in the energy sector should focus on renewable energy, which can reduce unemployment rates.

Pai et al. (2021) combined a 50-country dataset of job intensities throughout 11 energy technologies and five job categories, using an integrated assessment model under three shared socioeconomic pathways. Their results showed that under the "global warming to well below 2 degrees" scenario, energy sector jobs

would grow from 18 million to 26 million by the year 2050. They reported that employment in the fossil fuel sector will be lost but will also be compensated by wind and solar energy sectors.

Researchers studied the relationships between energy consumption and unemployment mainly using causality tests, but the literature offered on this topic is still limited. There is a lack of understanding of such relationships within the context of Jordan. This paper will fill this gap in the literature by utilising the Toda-Yamamoto technique to test the causality between renewable energy consumption and unemployment rates, including two national account indicators.

Data and methodology

Descriptive analysis

Annual data for the period 1991-2018 for Jordan were collected from the World Bank database. Table 1 shows the definitions of the variables used in this study. All the variable time series were transformed into natural logarithms. Natural logarithms are necessary for econometric analysis since they can minimise regression problems and define elasticity in the model (Wooldridge 2016; Saidu Musa–Rabiu 2020). The time series covers 28 years; data were collected from the World Bank database. The descriptive analysis results in Table 2 show the mean, the maximum, the minimum, the skewness, the kurtosis, and the Jarque-Bera probability for all the series.

The skewness coefficients show that all the series skewed positively, except general government final consumption, which was negatively skewed. The kurtosis values reveal that the general government's final consumption and gross fixed capital formation as a percentage of GDP are platykurtic. In contrast, renewable energy consumption and total unemployment rates are both leptokurtic. The results also show that all the variables deviate below their average mean values. The Jarque-Bera p-values show that the general government's final consumption and gross fixed capital formation as a percentage of GDP are normally distributed, while renewable energy consumption and total unemployment rates are not normally distributed within the time series period. Figure 1 shows more details on the trend of the time series. The trend of renewable energy consumption shows that consumption increased from 2015. Unemployment rates show a rising trend since 2014. General government's final consumption and gross fixed capital formation as a percentage of GDP show fluctuations during the study period, with a generally negative trend during the latest year of the record.

Table 1. Description of variables used in this study

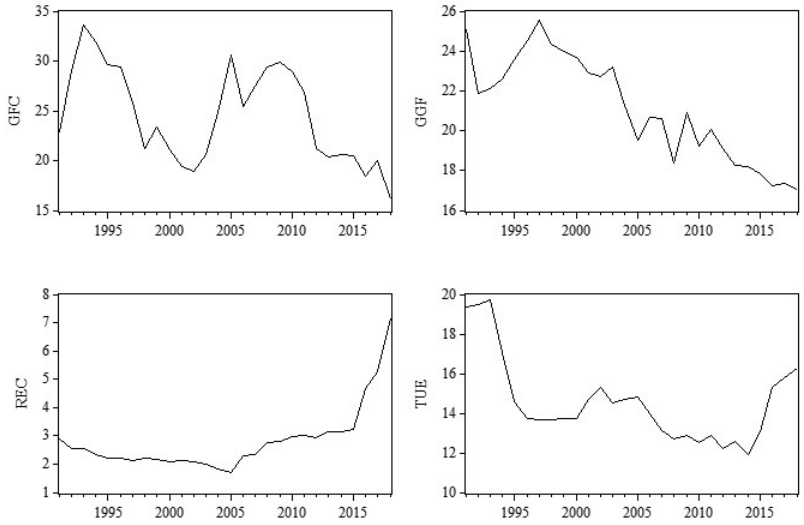
Variable	Description
REC	Renewable energy consumption as a percentage of total final energy consumption
TUE	Unemployment as a percentage of the labour force
GGF	General government final consumption expenditure as a percentage of GDP
GFC	Gross fixed capital formation as a percentage of GDP

Source: World Bank 2021

Table 2. Descriptive analysis

	REC	TUE	GFC	GGF
Mean	2.811	14.570	24.553	21.141
Median	2.432	13.870	24.099	21.110
Maximum	7.190	19.700	33.561	25.547
Minimum	1.688	11.900	16.125	17.058
Std. Dev.	1.161	2.141	4.793	2.613
Skewness	2.398	1.202	0.156	-0.026
Kurtosis	8.876	3.677	1.774	1.738
Jarque-Bera	67.104	7.280	1.868	1.861
Jarque-Bera p-value	0.000	0.026	0.393	0.394
Observations	28	28	28	28

Source: Own research based on World Bank 2021



Source: World Bank 2021

Figure 1. Trend in the selected time series used in the study

Unit root test

Economic time series show a trend in either mean, variance, or both (Das 2019). If the time series mean and variance remain constant, it is stationary (Szép 2014). Thus, the stationarity of the time series should be evaluated. Before testing, it is crucial to overcome the problem of non-stationarity; this can be done by first differencing and de-trending (Das 2019). There are multiple methods to test time series stationarity of unit root; among those, the most popular one is the augmented Dicky-Fuller (ADF) test developed by Dicky–Fuller (1979). The ADF test tends to reject the null hypothesis of non-stationarity. Another test, KPSS, is practical and used to confirm the results. Contrary to the ADF test, the KPSS test tends to accept the null hypothesis of non-stationarity. When testing the non-stationarity of the time series, we can choose from three options that we can include in the equation: first, there is no intercept or trend; second, only intercept but no trend; and third, including both an intercept and trend (Enders 2015).

Toda-Yamamoto Technique

To investigate the long-term relationship between renewable energy consumption and unemployment rates for the study period, we used the non-Granger causality test by Toda and Yamamoto (1995). No matter the order of integration of the series or whether they are cointegrated or not, the Toda and Yamamoto causality method is effective and applicable. This method applies to stationary time series at level, first difference, or second difference. The technique was structured based on the augmented Vector Autoregressive (VAR) modelling method and the Wald test statistic. The test is based on asymptotic chi-square (χ^2) values that are distributed regardless of the cointegration properties and the stationarity of the data series. In this technique, we estimate the $(k + d_{\max})^{\text{th}}$-order VAR where k is the determined lag length, and $d_{\max}$ is the maximal order of integration. Our study performed the Toda-Yamamoto long-run non-Granger causality test using VAR with four lags (k=3 and $d_{\max}$=1). The matrix form of the equation is written in equation (1).

$$\begin{bmatrix} lnREC_t \\ lnTUE_t \\ lnGGF_t \\ lnGFC_t \end{bmatrix} = \eta_0 + \eta_1 \begin{bmatrix} lnREC_{t-1} \\ lnTUE_{t-1} \\ lnGGF_{t-1} \\ lnGFC_{t-1} \end{bmatrix} + \eta_2 \begin{bmatrix} lnREC_{t-2} \\ lnTUE_{t-2} \\ lnGGF_{t-2} \\ lnGFC_{t-2} \end{bmatrix} + \eta_3 \begin{bmatrix} lnREC_{t-3} \\ lnTUE_{t-3} \\ lnGGF_{t-3} \\ lnGFC_{t-3} \end{bmatrix} + \eta_4 \begin{bmatrix} lnREC_{t-4} \\ lnTUE_{t-4} \\ lnGGF_{t-4} \\ lnGFC_{t-4} \end{bmatrix} + \begin{bmatrix} \mu_{lnREC} \\ \mu_{lnTUE} \\ \mu_{lnGGF} \\ \mu_{lnGFC} \end{bmatrix} \quad (1)$$

lnREC represents the log of renewable energy consumption, *lnTUE* represents the natural log of total unemployment rates, *lnGGF* is the general government final consumption expenditure log, and *lnGFC* describes the gross

fixed capital formation. η_1 ... ... η_4 represent the 4*4 matrices of quantities with η_0 identity matrix. The disturbance terms that have zero mean and constant variance is represented by μ_s.

Results and discussion

The correlation analysis is applied as a first step to make sure that multicollinearity does not exist. The correlation matrix cannot indicate causality, but on the other hand, all the variables should show no high multicollinearity (coefficient factors between -0.9 and 0.9) (Field 2009). Table 3 shows that the correlation between the variables is within the limits, and no multicollinearity exists. The correlation analysis outcomes show a significant negative correlation between renewable energy consumption, the general government's final consumption, and gross fixed capital formation as a percentage of GDP. It means that when renewable energy consumption increases, the two variables will decrease.

Table 3. Correlation Matrix of the variables

		lnGFC	lnGGF	lnREC	lnTUE
lnGFC	Pearson Correlation	1			
lnGGF	Pearson Correlation	0.301	1		
	Sig. (2-tailed)	0.12		0	
lnREC	Pearson Correlation	-.476*	-.710**	1	
	Sig. (2-tailed)	0.01	0		
lnTUE	Pearson Correlation	0.125	0.264	0.073	1
	Sig. (2-tailed)	0.525	0.175	0.712	

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Source: Own research

Table 4 shows that when testing the unit root using ADF with intercept only, the variables are stationary at first difference, except for renewable energy consumption. On the other hand, performing the analysis including both intercept and trend shows that all the variables are integrated at first difference. The KPSS test is employed to test the stationarity of the variables. KPSS test results are listed in Table 5. The results show that the null hypothesis of stationarity is accepted at the first difference when tested at intercept and trend at the 5% level (values of 5% level are between brackets).

Table 4. Unit root test using ADF test

	Maximum Lag (AIC)	ADF unit root test Intercept			ADF unit root test Intercept and trend		
		I(0)	I(1)	I(2)	I(0)	I(1)	I(2)
lnREC	**3**	2.069 (0.999)	-1.363 (0.584)	-10.185 (0.000)	0.095 (0.996)	-5.181 (0.002)	-10.020 (0.000)
lnTUE	**3**	-2.941 (0.054)	-3.222 (0.030)	-5.084 (0.001)	-2.051 (0.547)	-3.874 (0.028)	-4.789 (0.005)
lnGGF	**3**	0.012 (0.952)	-7.7337 (0.000)	-5.295 (0.000)	-2.839 (0.197)	-7.809 (0.000)	-5.134 (0.002)
lnGFC	**3**	-1.083 (0.708)	-4.501 (0.002)	-5.502 (0.000)	-1.885 (0.634)	-4.465 (0.008)	-5.280 (0.001)

Source: Own research

Table 5. Unit root test using KPSS test

	Maximum Lag (AIC)	KPSS unit root test Intercept			KPSS unit root test Intercept and trend		
		I(0)	I(1)	I(2)	I(0)	I(1)	I(2)
lnREC	**3**	0.521 (0.463)	0.563 (0.463)	0.105 (0.463)	0.206 (0.146)	0.073 (0.146)	0.085 (0.146)
lnTUE	**3**	0.374 (0.463)	0.319 (0.463)	0.085 (0.463)	0.130 (0.146)	0.074 (0.146)	0.074 (0.146)
lnGGF	**3**	0.730 (0.463)	0.071 (0.463)	0.136 (0.463)	0.118 (0.146)	0.061 (0.146)	0.088 (0.146)
lnGFC	**3**	0.278 (0.463)	0.174 (0.463)	0.111 (0.463)	0.088 (0.146)	0.078 (0.146)	0.110 (0.146)

Source: Own research

Using the VAR framework, optimum lag length criteria were applied. The results are listed in Table 6. Four criteria suggested that three lags were the optimum lags for our model estimation.

Table 6. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	55.46603	NA	1.91E-07	-4.11728	-3.92226	-4.06319
1	136.2399	129.2383	1.10E-09	-9.2992	-8.324094*	-9.02874
2	151.9559	20.11645	1.26E-09	-9.27647	-7.52129	-8.78966
3	180.6608	27.55666*	6.25e-10*	-10.29286*	-7.7576	-9.589688*

* Indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion

Source: Own research

To estimate the long-term cointegration relationship between the variables, the Johansen and Juselius test was conducted, and the test results are provided in Table 7. The results show that the null hypothesis of no cointegration is rejected. Moreover, the relationship exists in both the trace and max-eigen value statistics. This result implies that the series are cointegrated, and in the long term, they move together.

Table 7. Johansen and Juselius test for cointegration result

Hypothesis	Eigenvalue	Trace statistics	0.05 Critical Value	P-value
Trace Test Statistic				
None *	0.904*	105.115	63.876	0.000
At most 1 *	0.721*	48.944	42.915	0.011
At most 2	0.413	18.326	25.872	0.323
At most 3	0.206	5.537	12.518	0.521
Maximum Eigenvalue Test Statistic				
	Eigenvalue	**Max-Eigen Statistic**	**0.05 Critical Value**	**P-value**
None *	0.904*	56.170	32.118	0.000
At most 1 *	0.721*	30.618	25.823	0.011
At most 2	0.413	12.789	19.387	0.345
At most 3	0.206	5.537	12.518	0.521

* Denotes rejection of the hypothesis at the 0.05 level

Source: Own research

Table 8 details the causal links between unemployment rates and renewable energy consumption. The results indicate that the null hypothesis of no causality from all the variables toward unemployment is rejected. Renewable energy consumption has a solid causality relationship to unemployment rates where p-value is <0.05; this implies that investment in renewable energy can, in the long term, contribute to minimising unemployment rates. The results also show that gross fixed capital formation positively influences unemployment rates, indicating that capital formation catalyses employment in Jordan. Finally, a causal relationship is detected from general government final consumption expenditure towards unemployment rates but at a lower p-value than the previous indicators.

Our paper's findings support the literature reviewed. Regardless of the econometric method used in the mentioned literature, there is a general agreement that renewable energy consumption causes unemployment. Nevertheless, some

findings suggest that there is a causal relationship between the two sides. These findings demonstrate the close association between the two factors and the impact of developing renewable energy sources on lowering unemployment rates. The results also show that Jordan can benefit from diversifying the energy system and reducing the unemployment rates in the country by creating new opportunities in the energy sector.

Table 8. Toda-Yamamoto causality test results

Null Hypothesis	Chi-Square (χ^2)	P-value
Renewable energy consumption does not cause unemployment	9.402	0.024
Gross fixed capital formation does not cause unemployment	8.929	0.030
General government final consumption expenditure does not cause unemployment	7.164	0.067
Unemployment does not cause renewable energy consumption	1.707	0.635
Unemployment does not cause general government final consumption expenditure	2.356	0.502
Unemployment does not cause the gross fixed capital formation	0.686	0.877
Gross fixed capital formation does not cause renewable energy consumption	0.452	0.929
General government final consumption expenditure does not cause renewable energy consumption	0.816	0.846
General government final consumption expenditure does not cause the gross fixed capital formation	0.366	0.947
Gross fixed capital formation does not cause general government final consumption expenditure	0.817	0.845
Renewable energy consumption does not cause the gross fixed capital formation	1.213	0.749
Renewable energy consumption does not cause general government final consumption expenditure	5.619	0.132

Source: Own research

Conclusions

This study examined the causal relationship between renewable energy consumption and unemployment in Jordan over the period of 1991-2018 using the Toda and Yamamoto causality technique. The study builds on the previous literature, and its results confirm the previous studies and highlight the importance of investing in developing renewable energy resources. In the literature review section, the previous works showed that renewable energy consumption could play a significant role in creating jobs; this also applies to Jordan, as the results revealed.

Jordan has the potential to lead the efforts in the Middle East in terms of utilising renewable energy resources because of its unique location and the high number of sunny days.

The study revealed that there is a causal relationship running from renewable energy consumption towards unemployment; this gives a strong indicator that, in the long term, investing in renewable energy can contribute to reducing unemployment rates in the country. Moreover, the outcomes showed that both gross fixed capital formation and general government final consumption cause unemployment, which leads to the conclusion that a capital increase can lead to creating more job opportunities.

The results suggest that unemployment rates in the energy sector can be reduced by increased production and consumption of renewable energy. Constraints to investment in the industry should be removed by lowering taxes and initial prices while improving the infrastructure. Promoting private sector investment in the field of renewable energy can open up new employment opportunities. Future research in Jordan should concentrate on the role of renewable energy in boosting energy security, equality, and energy transition as more nations around the world move toward increasing the share of renewables in the energy mix.

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