Analysis of selected economic factor impacts on CO_2 emissions intensity: A case study from Jordan, 1990–2015

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This study investigates the possible impacts of selected economic factors on carbon dioxide (CO2) emissions intensity in Jordan. The energy industry is one of the main sectors that have an impact on greenhouse gas emissions in Jordan, with a total share of 73% of emissions emanating from only this sector according to the 2006 emissions inventory. In this study, energy intensity, gross domestic product (GDP) per capita, labour force, and primary energy consumption are analysed using the Granger causality test and the path analysis for identifying the factors that mostly impact energy intensity vis-à-vis CO_2 emissions intensity. The analysis is undertaken in order to study the changes in energy intensity and the possible impacts on CO_2 emissions intensity. The results show that energy intensity has a direct impact on CO_2 emissions intensity, as proven by both path analysis and the Granger causality test. Moreover, the most effective indirect path is that of running through the labour force, followed by the path that contains GDP per capita. In conclusion, while considering the necessity of Jordan's economic development, there should be a focus on sustainability, improving technology, and supporting renewable energy projects.

Keywords:
energy intensity,
climate change,
causality analysis,
path analysis,
Jordan

Introduction

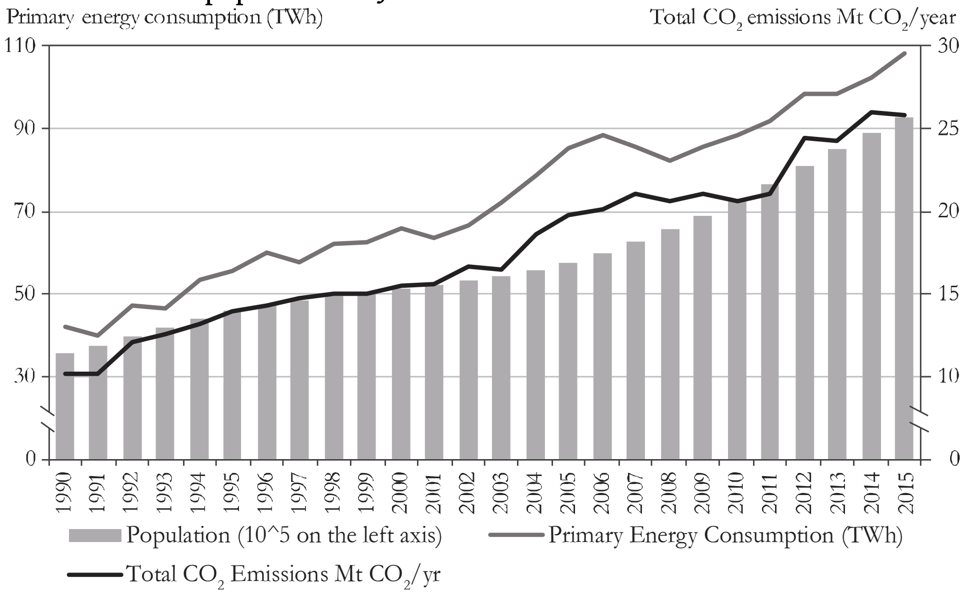
Dependency on burning fossil fuels increases air pollutant emissions and greenhouse gases (GHGs), especially carbon dioxide (CO_2) (Hamdi et al. 2009). Focusing on the higher CO_2 contents in the atmosphere, all these processes lead to the climate change problem of the modern world, which affects every form of life on earth. Fossil fuel-based energy consumption is one of the main engines that drive the generation of GHG emissions. While energy is the main driver of economic activities, more attention is given to global warming and climate change; thus, research efforts have been geared towards the relationship between unsustainable energy consumption, economic growth, and environmental pollutants (Pao et al. 2011, Arouri et al. 2012, Jamel et al. 2016, Song et al. 2019, Mitsis 2021, Ghalehteimouri et al. 2021).

In 2007, the Jordanian Government introduced a transformation strategy, which included a higher proportion of renewable energy resources, oil shale, and nuclear energy, to decrease the reliance on oil and natural gas in the energy mix (Ministry of Energy and Natural Resources 2016). Fossil fuel is the major source of energy in Jordan, and although it plays a pivotal role in increasing GHG emissions, energy consumption is important in sustaining economic and social development.

Since 1990, the primary energy consumption of Jordan has increased dramatically with a notable rise in CO_2 emissions, too. This has mainly resulted from the rapid population growth. Figure 1 shows a strong correlation between primary energy consumption, CO_2 emissions, and population growth.

Figure 1

Change in primary energy consumption, CO_2 emissions, and population in Jordan between 1990 and 2015



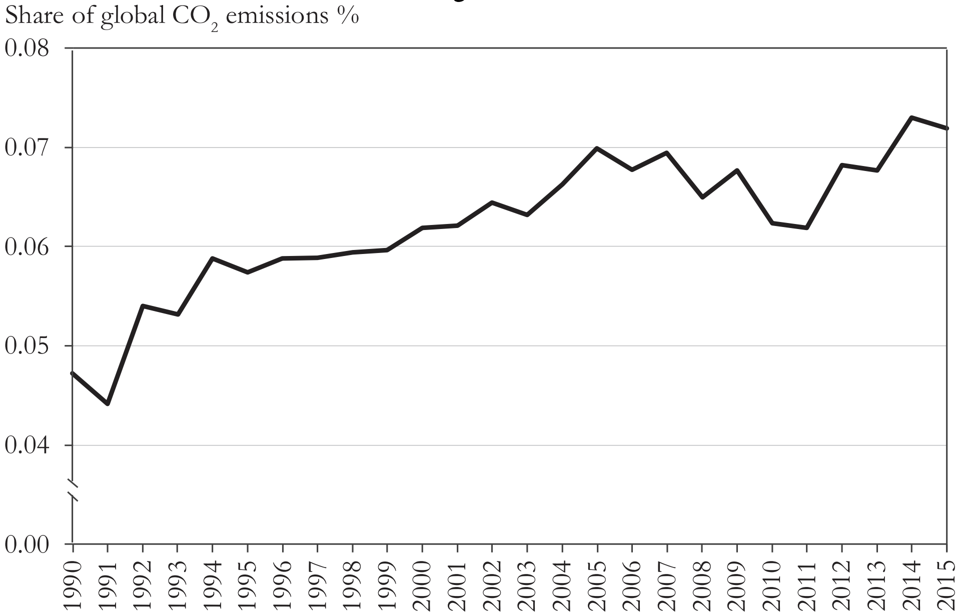
Sources: (Ritchie–Roser (2020), Worldbank (2021b).

According to Jordan's Third National Communication Report on Climate Change (UNFCCC 2015), and based on the 2006 GHG emissions inventory, the energy sector (including transportation) has contributed to 73% of the total GHG emissions. In 2015, Jordan signed and ratified the Paris Agreement, which resulted in the submission of the official Intended Nationally Determined Contributions (INDCs), whereby Jordan pledged to reduce its GHG emissions by 14% below the

‚business as usual' target by the year 2030. Of these emissions, 12.5% were conditional to the availability of international financial aid and implementation support (UNFCCC 2015). Additionally, as of 2017, the Jordanian Government, in collaboration with the Global Green Growth Institute, prepared and published the National Green Growth Plan, which identified six sectors, including the energy sector, with high growth potential. The Plan identified Jordan as insecure vis-à-vis energy resources because of the reliance on external resources; consequently, renewable energy, represented by solar energy, was posited as the main source of greening the energy sector (Ministry of Environment 2018). In general, the percentage of GHG emissions produced in Jordan is low. Figure 2 shows the annual share of global CO_2 emissions in Jordan to be less than 0.075%, which indicates that Jordan is still considered to be affected by climate change, although not a major contributor compared to the pledged INDCs. Moreover, upon evaluating the CO_2 emission intensity in Jordan between 1990 and 2015, there is an annual decrease in emission trend (Figure 3) by 1.26%, where 2010 and 2011 have the lowest emission values of 0.3 t CO_2/kUSD/year. Notably, after the global financial crisis, CO_2 emissions have grown rapidly (Peters et al. 2012), as applicable to Jordan.

Figure 2

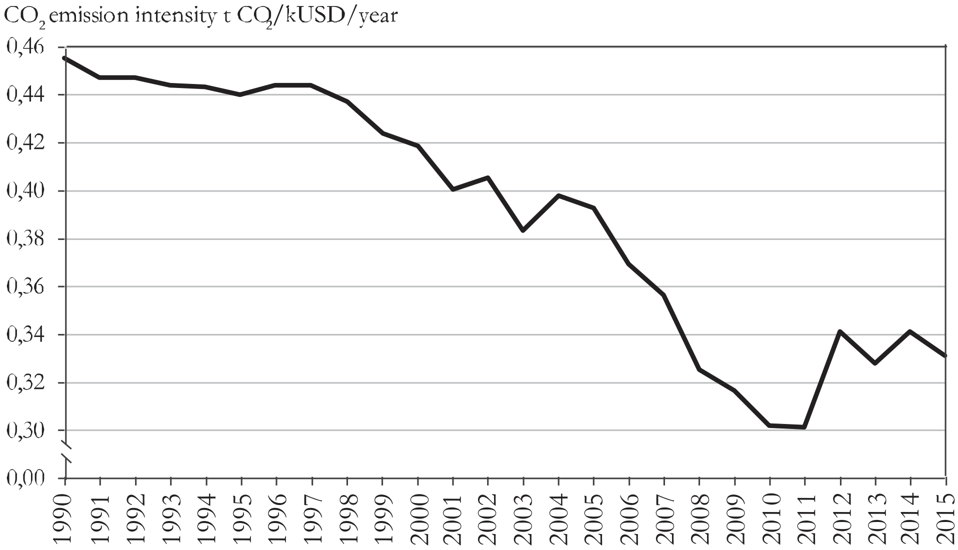
Annual share of global CO_2 emissions



Source: Ritchie–Roser (2020, p. 2).

Figure 3

Jordan's CO_2 emission intensity between 1990 and 2015



Source: Monforti-Ferrario et al. (2019).

Research efforts on the relationship between economic growth and energy consumption have been ongoing for a long time, and several researchers have elucidated these connections using different methods. Acaravci and Ozturk (2010) examine the long-run causal relations between CO_2 emissions, energy consumption, and economic growth using an autoregressive distributed lag and the Granger causality test for 19 European countries. Their results show a long-run causal relationship between energy consumption and CO_2 emissions and a long-run elasticity between carbon emissions and real gross domestic product (GDP). Arouri et al. (2012) test the environmental Kuznets curve (EKC) hypothesis in the Middle East and North Africa (MENA) region by applying bootstrap unit root tests and a panel cointegration method to explore the relationship between real GDP, energy consumption, and CO_2 emissions. Their results show that EKC is only verified for Jordan and the fact that in the long run energy consumption has a high impact on CO_2 emissions in the region. Hamit-Haggar (2012) applies cointegration analysis to investigate the long-term relationship between GHG emissions, energy consumption and economic growth for the Canadian industrial sector. The findings of the analysis reveal that there is a significant long-run impact of energy consumption on GHG emissions, whereas there is a non-linear relationship between GHG emissions and economic growth, which is consistent with the EKC. Mugableh (2015) investigates the equilibrium and dynamic causality relationships among economic development, CO_2 emissions, energy consumption, financial development, foreign direct investment inflows, and gross fixed capital formation in Jordan between 1976 and 2010. One of the main results of the paper is that the EKC hypothesis exists between economic development and CO_2 emissions in the long and short run. The results also indicate strong evidence of unidirectional causality from financial development to energy and growth in Jordan. Saidi–Hammami (2015) investigate the impact of economic growth and CO_2 emissions on energy consumption for 58 countries using the generalised method of moments. They find that CO_2 emissions correlate positively with energy consumption for all the sample countries – Europe and North Asia, Latin America and the Caribbean, as well as the MENA and the Sub-Saharan African regions. However, economic growth is positively correlated with energy consumption in the MENA and Sub-Saharan African region. Spetan (2016) investigated the causal relationships between renewable energy consumption, CO_2 emissions, labour, capital, and economic growth in Jordan from 1986 to 2012. Results showed that in the short run, bidirectional causality is running from capital and renewable energy consumption, a unidirectional causality is running from renewable energy consumption to real GDP, a unidirectional causality running from real GDP to capital, and unidirectional causality from renewable energy consumption and CO_2 emissions. It concluded that CO_2 emissions can be reduced with an increase in renewable energy consumption. Gui et al. (2017) use the ‚partial least square' method path analysis combined with a regression model to investigate the factors that influence CO_2 emissions intensity. The factors included in the study are GDP per capita, technology effect, energy price, industrial structure, energy structure, and foreign direct investment. The results show that carbon intensity is mainly affected by the technology effect. Moreover, the study stresses that research and development is playing an important role in controlling carbon intensity in China. Chen–Lei (2017) study the transportation sector as one of the main driving forces that produce higher CO_2 emissions. They use the path analysis model to estimate the direct, indirect, and total influence of driving factors on CO_2 emissions in Beijing. The results show that controlling transportation-related CO_2 emissions can be reduced if both energy and transportation intensities are lowered. Furthermore, it is indicated that population has the most significant impact on CO_2 emissions, as population growth will increase the pressure on the transportation sector.

In this study, a path model based on SPSS is used to estimate the effects of different factors on CO_2 emissions intensity. To the best of my knowledge, this is the first time that such a methodology is used in this context. The Granger causality test is used to elucidate the relationship between energy intensity and CO_2 emissions intensity in Jordan and to provide a better understanding of the causal effects running between these two factors.

Data and methodology

In this study, the Granger causality test and path analysis are employed to understand the factors affecting CO_2 emissions intensity in Jordan. The data used in this study are collected from different sources because of issues related to data availability and credibility. The data are collected from three different sources – World Bank databases (Worldbank 2021a), Emission Database for Global Atmospheric Research (Monforti-Ferrario et al. 2019), and Our World in Data project website (Worldbank 2021c). Data range from 1990 to 2015. Table 1 presents a description of the selected variables for this study, and the selected data are based on the review of the related literature as well as the availability of the selected data in a Jordanian context.

Table 1

Definition of factors

Observational variable	Definition	Unit	Source
Energy intensity	The ratio between energy supply and gross domestic product	kWh per USD	Our world in data database
GDP/capita	GDP divided by the population, in constant 2010 price	constant 2010 USD	World Bank
Total labour force	The labour force comprises people aged 15 years and older who supply labour to produce goods and services during a specific period. It includes people who are currently employed and people who are unemployed but seeking jobs, as well as first-time jobseekers	Annual Sum	World Bank
Primary energy consumption	Primary energy consumption is measured in terawatt-hours (TWh)	Terawatt-hours (TWh)	Our world in data database
CO_2 emissions intensity	CO_2 emissions per unit of GDP	tCO_2/kUSD/year	EDGAR report

Granger causality test

As path analysis is not intended to explain the causal effect relationship between variables, it is important to utilise other methodologies, as this would improve the results and test whether the long-run change in the primary explanatory factor will affect the dependent variable. To test causality, first, the stationarity of the data should be evaluated, which means that the mean and variance remain constant through time (Sebestyén 2014). Testing stationarity or unit root can be achieved using multiple methodologies, and the most popular test is the augmented Dickey–Fuller one, developed by Dickey–Fuller (1979). The testing can include three options; depending on the time series of interest, the calculations may consider that there is no constant or trend, or only constant but no trend, and there are both a constant and a trend (Enders 2015). Herein, the calculation will be based on the third case using the following equation:

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \quad (1)$$

where Y_t is the economic variable in time t, ΔYt–1=Yt–1–Yt–2, and εt is the residual term. The augmented test includes lagged changes to test the null hypothesis of γ = a0 = 0.

According to Granger (1969), X variable Granger causes Y variable, but Y does not Granger cause X:

$$Y_t = \sum_{i-1}^{p} a_i Y_{t-1} + \sum_{j-1}^{q} \beta_j X_{t-j} + u_t \quad (2)$$

where u_t is the white noise, p is the lag order of the Y variable, and q is the lag order of the X variable. The white noise is normally, independently, and identically distributed with a mean of zero (Sebestyén 2014). The test is made based on the assumption that the number of lags ranges from 1 to 3 by considering that a higher number of lags will increase the error in calculations because the number of observations is not high (26-year data). Determining the lags is done by using the Schwarz information criterion (SIC).

As the Granger causality test is intended to study the nexus between energy intensity and CO_2 emission intensity, some policy-related assumptions can be made based on four hypotheses (growth, conservation, feedback, and neutrality). First, the growth hypothesis posits that if there is a unidirectional causality running from energy intensity to CO_2 emissions intensity, energy intensity will have a significant impact on CO_2 emissions intensity. Consequently, any reduction in the energy intensity will result in an adverse influence on CO_2 emissions intensity. Second, the conservation hypothesis infers that if there is a unidirectional causality running in the opposite direction, the efforts to reduce energy intensity will not lead to a significant reduction in CO_2 emissions intensity. Third, the feedback hypothesis is based on the assumption that there is a bidirectional causality relationship between the two variables. Finally, the neutrality hypothesis implies that there is little or no influence of both variables on each other.

Path analysis

Although the path analysis concept is not new, it is a novel method in the field of energy economics and climate change. First, path analysis uses both simple and multiple linear regressions in the field of spatial statistics (Tóth–Kincses 2014, Kovács–Bodnár 2017, Szabó 2019). Second, the structural equation modelling concept deploys partial least square analysis to find the causal relationship between factors (Li et al. 2011). Path analysis uses multiple regression to explicitly formulate causal models. Causality cannot be established using this method; it can examine the pattern of relationships between three or more variables, but it can neither confirm nor reject the hypothetical causal imagery. This type of analysis aims to provide quantitative estimates of the causal connections between sets of variables (Bryman 2004). Path analysis is conducted to estimate the direct and indirect effects that influence CO_2 emissions intensity in Jordan. Figure 4 shows the path diagrams of the factors that are included herein.

The model is measured based on the typical factor analytic with the assumption that the explanatory variable influences the outcome variable:

$$Y = \beta Y + \gamma X + \varepsilon \quad (3)$$

where Y is the vector of observable dependent variables, X is the vector of observable independent variables, ε is the vector of errors, and β, γ are coefficient matrices.

The linear multiple regression is as follows:

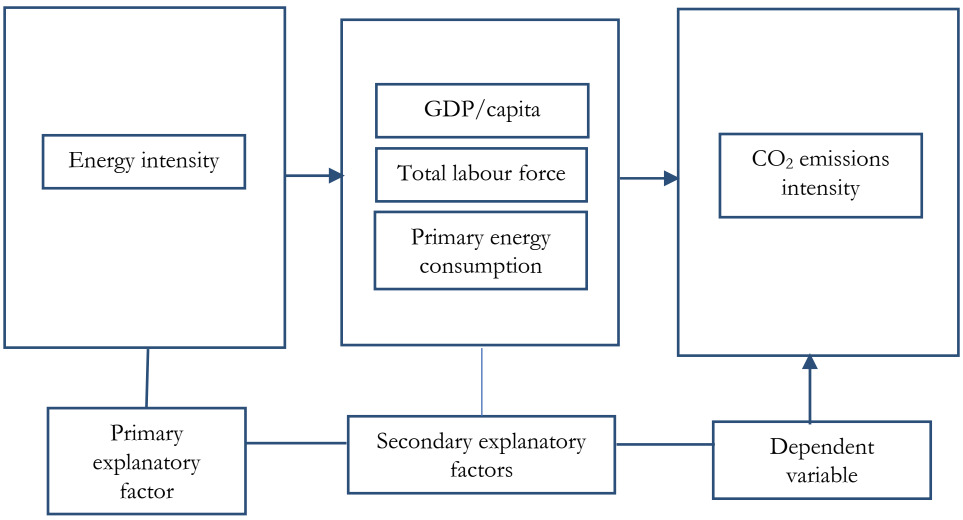
$$y_i = \beta_0 + \beta_1 x1_{1,i} + \beta_2 x1_{2,i} + \cdots + \beta_k x1_{k,i} + \epsilon_i \quad (4)$$

where k is the number of explanatory variables.

Path analysis is established by deleting the non-significant path and estimating the residual coefficient through the standard regression path coefficient (Chen–Lei 2017).

Figure 4

Path diagram of the group of explanatory variables



The diagram clearly shows three types of variables connected by arrows, which represent the direction of the model. The primary explanatory variable is based on the assumption that energy intensity has a direct effect on CO_2 emissions intensity ‚zero-order linear correlation'. The secondary explanatory variables are those that may have an indirect effect on the dependent variable, while they are simultaneously affected by energy intensity ‚GDP per capita, labour force, and total primary energy consumption'. Thus, the model basically performs a chain of simple linear regressions to find the best interpretation of the relationships between the explanatory factors and the targeted (dependent) variable. This method is simple and can reveal the desired relationships between the variables under study.

Results and discussion

In this section, the results for both Granger causality test path analyses will be summarised and discussed. Table 2 lists the variables with their statistical descriptions.

Table 2

Statistical description of the variables

Variable	Mean	Std. Deviation	N
CO_2 emissions intensity	0.39	0.05	26
GDP per capita	3,105.81	445.00	26
Labour force, total	1,467,435.58	432,209.42	26
Primary energy consumption	72.66	19.76	26
Energy intensity	2.67	1.02	26

Granger causality test

The results for the causality test are shown in the first part followed by the path analysis results.

Unit root test

Table 3

Results of augmented Dickey–Fuller unit root test for energy and CO_2 intensity

Variable	Lag length	ADF statistics	Critical value 5%	Probability	Conclusion
Level					
Energy intensity	3	–2.592237	–3.603202	0.2863	Unit root
CO_2 emissions intensity	3	–3.359668	–3.632896	0.0830	Unit root
First difference					
Energy intensity	3	–4.409710	–3.612199	0.0097	No unit root
CO_2 emissions intensity	3	–3.747991	–3.644963	0.0412	No unit root
Second difference					
Energy intensity	3	–9.905432	–3.622033	0.0000	No unit root
CO_2 emissions intensity	3	–10.12774	–3.622033	0.0000	No unit root

As noted in Table 3, at the level, the series is not stationary, which means that we cannot reject the null hypothesis. Meanwhile, after testing at the first and second difference, both series show that they are stationary, and this result is used to test cointegration in the next section.

Johansen's cointegration test

As the unit root test shows that the two variables are stationary at the first difference level, cointegration is tested. Johansen's cointegration approach is used to determine whether the variables are bound by a long-run relationship. In this step, the differenced variables are tested by using simple, unrestricted vector autoregression. The results are shown in Table 4.

Table 4

Unrestricted cointegration rank test (trace)

Hypothesised No. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.*
None*	0.690044	34.41412	18.39771	0.0001
At most 1*	0.324939	8.644943	3.841466	0.0033

* Rejection of the hypothesis at the 0.05 level.

Based on the trace method, the null hypothesis of ‚no cointegration' is rejected. This indicates that there is cointegration at the 0.05 level. The results of the unrestricted cointegration rank test using the maximum eigenvalue method are shown in Table 5. The null hypothesis of no cointegration is rejected as well.

Table 5

Unrestricted cointegration rank test (maximum eigenvalue)

Hypothesised No. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 critical value	Prob.*
None*	0.690044	25.76918	17.14769	0.0022
At most 1*	0.324939	8.644943	3.841466	0.0033

* Rejection of the hypothesis at the 0.05 level.

According to the maximum eigenvalue test, it also indicates that there is cointegration at the 0.05 level, which means that the null hypothesis is rejected.

Results of the Granger causality test

The Granger causality test is performed based on several lags ranging from 1–3 using the SIC to determine the optimal results. Selecting the lags can affect the precision of the analysis (more lags may decrease the observations included in the calculations and thereby diminish the precision of the results). The results of the Granger test are shown in Table 6. The table clearly indicates a causality relationship running from energy intensity towards CO_2 emissions intensity (Growth hypothesis), which proves that more energy consumed per unit GDP will result in increased emissions in Jordan. Additionally, the results show that if more policies target the increment of the share of renewable resources, the energy sector-based emissions will decrease (Müller-Frączek 2019, Lados et al. 2020).

Table 6

Results of the Granger causality test for no causality between CO_2 emissions intensity and energy intensity

Null hypothesis	Observations	F-Statistic	Prob.	Decision
Energy intensity does not Granger cause CO_2 emissions intensity	23	5.78222	0.0071	Causality detected
CO_2 emissions intensity does not Granger cause energy intensity	23	0.74125	0.5429	No causality

Path analysis

The results of the zero-order linear correlation are listed in Table 7, and they show a positive correlation between energy intensity and CO_2 emissions intensity with a beta value of 0.932. Table 7 confirms the results indicated in the Granger causality test.

Table 7

Zero-order linear correlation for energy intensity and CO_2 emissions intensity

Model		Unstandardised coefficients		Standardised coefficients	t	Sig.	Collinearity statistics	
		B	Std. error	Beta			tolerance	VIF
1	(Constant)	0.263	0.011		24.462	0.000		
	Energy intensity	0.048	0.004	**0.932**	12.636	0.000	1.000	1.000

Note: Dependent variable: CO_2 intensity.

The second step of the model is to calculate the linear regression between energy intensity as an independent factor and other factors; the dependent factor is changed in each step in the calculation. Table 8 presents a summary of the results, and all the beta values are negative, indicating that any change in any of these would lead to a negative change in energy intensity. Furthermore, the significance values are also less than 0.05, which shows that these factors are impactful.

Table 8

Summary of regression analysis investigating the relationship between energy intensity and the other variables

		GDP/capita	Labour force	Primary energy consumption
Energy intensity	Beta	–0.820	–0.887	–0.841
	R^2	0.673	0.788	0.706
	P-value	0.0000	0.0000	0.0000

The third step in the analysis is to calculate the linear regression for all the variables, where CO_2 emissions intensity is the dependent variable, and the rest are independent. The R^2 value is 0.968. The results are listed in Table 9. The beta values indicate that only energy intensity and primary energy consumption have a positive relationship with CO_2 emissions intensity, which shows that more consumed energy would lead to an increase in the emissions to the atmosphere. However, the beta values for both GDP per capita and labour force have a negative value, indicating an insignificant relationship. Finally, the significance levels for all the factors are less than 0.05, which further confirms that there is a strong relationship therein.

Table 9

Regression analysis results between CO_2 emissions intensity and all the variables

Model		Unstandardised coefficients		Standardised coefficients	t	Sig.
		B	Standard error	Beta		
1	(Constant)	0.606	0.046		13.318	0.000
	Energy intensity	0.012	0.005	**0.236**	2.230	0.037
	GDP per capita	–7.159E-05	0.000	–0.610	–6.083	0.000
	Labour force, total	–8.785E-08	0.000	–0.727	–3.388	0.003
	Primary energy consumption	0.001	0.001	**0.535**	2.510	0.020

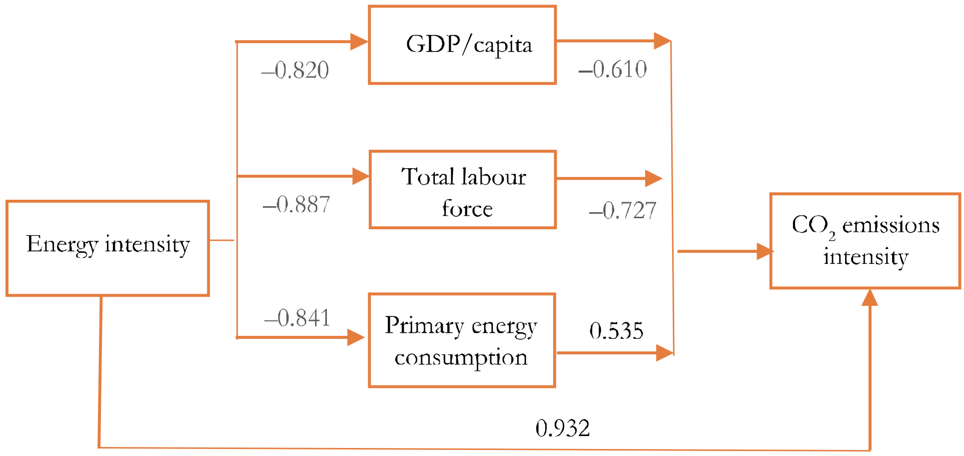
Note: Dependent variable: CO_2 emissions intensity.

The total effect can be calculated by multiplying the beta values for each factor from the second and third steps and then summing them up to find the total indirect path, which is equal to 0.692. The direct path beta coefficient is 0.236. By summing both the indirect and direct paths – the total causal effect, in this case – is equal to 0.932, which is equal to the zero-order beta value of 0.932, indicating that the calculations are correct.

Figure 5 shows that the most important path is energy intensity → CO_2 emissions intensity with a beta value of 0.932, which represents the zero-order path. Notably, the results of this path agree with that of the causality test in the previous section. Next, the indirect path of energy intensity → labour force → CO_2 emissions intensity is the most effective indirect path with a total value of 0.646, followed by the path that includes GDP per capita with a total value of 0.501, where the path that includes the primary energy consumption is negligible because its total value is –0.450.

Figure 5

Role of energy efficiency in Jordan in explaining GHG emissions



Note: The insignificant values are marked in grey.

Conclusions

The relationships between energy intensity, some selected economic factors, and CO_2 emissions intensity are investigated in this study by employing the Granger causality test and path analysis. Five variables – energy intensity, GDP per capita, labour force, primary energy consumption, and CO_2 emissions intensity – are used to construct the path model. The main finding of the Granger causality test supports the growth hypothesis, a unidirectional causal relationship running from energy intensity towards CO_2 energy intensity, thereby indicating that CO_2 emissions intensity is highly affected by energy intensity, and promoting policies that support energy efficiency enhancing, which, on their turn contribute to decrease CO_2 emissions. Moreover, the constructed zero-path also confirms the result provided by the Granger causality test.

In the path analysis, the indirect path shows that labour force has the most significant impact, followed by GDP per capita and, lastly, primary energy consumption. Improving GDP per capita may cause technological advances that contribute to the reduction of emissions impact.

Finally, it can be concluded that, in the case of Jordan, economic growth is necessary. However, it should be focused on sustainability, improving technology, supporting renewable energy, and making a transition that reduces CO_2 emissions, while facilitating the achievement of the INDCs submitted by the Jordanian government to the UNFCCC. Policies should be implemented with a focus on energy transition and on increasing the share of renewable resources in the energy production process.

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