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THE INTERPLAY BETWEEN NATURAL GAS CONSUMPTION, OIL CONSUMPTION, AND ECONOMIC GROWTH: AN EMPIRICAL EVIDENCE

Abstract. *The study examines and analyses the causality relationships between energy consumption, economic growth, trade, urbanisation, and industrialisation in the Caspian countries during the period from 1998 to 2021. In order to investigate the implications and effects of the energy consumption on the economic activity in this region, we computed two functions which include the following independent variables: global natural gas price, natural gas production, oil consumption, global oil price, oil production, GDP per capita, exports, imports, industrialisation, and urbanisation. By applying the Johansen cointegration test and the panel fully modified ordinary least square (FMOLS) regression method, the results showed that natural gas variables and oil variables are cointegrated in the mentioned period. Natural gas consumption and oil consumption were shown to have a positive impact on the level of GDP per capita in the long run. The results of the Dumitrescu-Hurlin causality test revealed the important and essential vital role of the natural gas and crude oil in underpinning and continuously supporting the efficiency of the energy sector within the Caspian countries, while the growth, conservation, and feedback hypotheses are confirmed. A major*

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implication of this study is to improve the energy security within the Caspian countries by establishing and building energy partnerships in the near future.

***Keywords**: energy consumption, economic growth, causality relationships, cointegration tests, energy security, Caspian countries, feedback hypothesis.*

JEL Classification: C33, Q40, Q41, Q43, Q47

1. Introduction

The energy resources, in particular natural gas and crude oil, are the main motors that drive the entire economic activity in a country. From this perspective, it is increasingly attractive to examine the positive effects and series of externalities that the energy resources provide in the economy. Most empirical studies (Akinsola and Odhiambo, 2020; Destek, 2016; Kum et al., 2012; Kaplan et al., 2011; Beyca, 2019) are focused on the determination and assessment of the causal relationships between the consumption and the production of domestic energy resources on the economic growth as well as economic development. In this respect, the authors create a series of hypotheses, namely: the growth hypothesis (describes a unidirectional causality from energy consumption to economic growth); the conservation hypothesis (provides a unidirectional causality from economic growth to energy consumption); the feedback hypothesis (generates the causal relationship between energy consumption and income); and the neutrality hypothesis (shows the no causality between income and energy consumption). At the same time, empirical studies show an intense concern among governmental authorities in terms of energy to create a nature-friendly environment (Jahangir and Dural, 2018; Balitskiy et al., 2016; Bilgili et al., 2016; Kum et al., 2012; Ozturk and Al-Mulali, 2015; Pirlogea and Cicea, 2012).

Given that energy security is becoming very important nowadays and this is mainly regarded from the security of demand and as well as security of energy transportation and energy supply, the central objective of our study is to examine and to determine the short- and long-term causal relationships between energy consumption-energy production-economic growth-trade-industrialisation-urbanisation for the five states of the Caspian Region (i.e., Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan) in the period 1998-2021. We are aware that the Caspian Countries play a significant role in the global energy markets and have been increasing their role in the recent period (here, we refer to their efforts to create new export routes and attract foreign investment in order to improve the production and extraction of energy resources). It is statistically shown that these countries in the Caspian region, particularly Azerbaijan, Kazakhstan and Turkmenistan, have high-value natural resource-based economies, where the oil and gas comprise more than 10 percent of their GDP and 40 percent of their exports (Jahangir and Dural, 2018; Emadi and Nezhad, 2011; Vedadi Kalanter et al., 2021).

In this regard, the research questions are as follows: **(1)** What is the impact of the energy consumption (i.e., oil consumption and natural gas consumption) on economic growth in the Caspian Region? **(2)** What is the impact of the global oil price and natural gas price on economic growth in this region?; **(3)** What are the main causality relationships between energy consumption and economic growth in this region?

In terms of methodology, we propose to determine and investigate in which way the natural gas consumption and the oil consumption cause short- and long-term effects on the economic activity in the five Caspian countries between 1998 and 2021. Here, we build two econometric models, which are able to assess the causality relationships between the natural gas consumption (NGC) and oil consumption (OC) on the economic activity in the Caspian Countries. In addition, we implement the VAR/VEC methodology, which is widely used in the empirical studies (Das et al., 2014; Emadi and Nezhad, 2011; Jahangir and Dural, 2018; Kaplan et al., 2011; Chu, 2012; Kum et al., 2012; Ighodaro, 2010; Narayan and Smyth, 2007; Vedadi Kalanter et al., 2021), which involves checking the stationarity condition for each time series, performing the cointegration tests, the short-and long-run coefficient estimation, conducting the robustness and diagnostic tests of these models. At the same time, the causal relationships were determined by applying the Dumitrescu-Hurlin panel causality test (Dumitrescu and Hurlin, 2012), and the long-term effects could be detected by applying the FMOLS cointegration regression. The structure of the paper is as follows: Section 2 presents the research methodology and the data sets used in our research; Section 3 provides the results; and discussions of the results and Section 4 concludes and addresses several policy implications based on our study.

2. Research methodology

2.1. The motivation and the variables used

The main objective of our study is to identify, determine and assess the short- and long-run causal relationships between energy consumption, energy production, economic growth, trade (in terms of exports and imports), industrialisation and urbanisation within the five Caspian countries (Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan) during the period from 1998 to 2021. For this purpose, we develop two functions regarding natural gas consumption (NGC) and oil consumption (OC), in order to detect and determine the interdependence and causality relationships that are established between the consumption of energy resources and the variables. These consumption functions are shown in Equation (1) and Equation (2).

$$NGC_{it} = f\left(NG_{PRICE_{it}}; NGP_{it}; GDP_{CAP_{it}}; EXP_{it}; IMP_{it}; IND_{it}; URB_{it}\right) \quad \textbf{(1)}$$

Where: i represents the country$(i = 1\ to\ 5)$ and t represents the time/period.

$$OC_{it} = f\left(O_{PRICE_{it}}; OP_{it}; GDP_{CAP_{it}}; EXP_{it}; IMP_{it}; IND_{it}; URB_{it}\right) \quad \textbf{(2)}$$

Where: i represents the country $(i = 1\ to\ 5)$ and t represents the time/period.

The Caspian countries were chosen because of the advantages and benefits of being endowed with traditional energy resources, especially natural gas and oil. We are aware that they are important countries for the production, trade, and export of energy resources; from this perspective, the estimation and determination of long-term causal relationships regarding the consumption of natural gas and oil is gaining increasing and growing attention for the policy makers (Ighodaro, 2010; Apergis and Payne, 2010; Ozturk and Al-Mulali, 2015).

In accordance with the relevant literature (Aimer and Hamoudi, 2018; Destek, 2016; Kaplan et al., 2011), we use GDP per capita as a variable describing the whole economic activity for the analysed countries, with the aim of showing the real dynamics over time in terms of economic growth or economic decline. In this way, this variable allows us to identify and capture in a concrete way the evolution of the growth rate of the economy for the Caspian countries, as well as how the GDP per capita can have a substantial impact on the consumption of the Caspian energy resources.

Together with GDP per capita, we used the following explanatory variables: natural gas production (NGP) and oil production (OP), referring to their roles as the main producers and exporters of energy commodities, but also to assess their impact on the evolution of natural gas consumption and oil consumption. Here, we mention the several studies carried out by Apergis et al. (2010); Chu (2012); Beyca et al. (2019), according to which the growth hypothesis (from energy consumption to economic growth) has been confirmed at the level of energy exporting countries. At the same time, we also included some macroeconomic indicators that illustrate the trade balance and the degree of trade openness, namely exports (EXP) and imports (IMP). These macroeconomic indicators are often used in empirical research (Akinsola and Odhiambo, 2020; Aimer and Hamoudi 2018; Das et al., 2014), and their analysis can provide important insights for the efficiency and improvement of energy trade and trade relations.

Moreover, among the explanatory variables, we have included the global oil price and the global natural gas price, with an increasing/increasing/recurring influence on the dynamics of demand and supply of energy resources within the closed domestic/domestic markets for the five Caspian countries. Taking into account some weaknesses and possible energy and national security threats for the majority of the Caspian countries examined, we considered the degree of urbanisation (URB) and industrialisation (IND) as the relevant socio-economic variables that provide a better assessment for the short-run and long-run relationship between the natural gas and oil variables. We use annual frequency data for the period from 1998 to 2021 among the Caspian countries: Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan. The total number of observations is 120, resulting from five Caspian Countries (cross-sectional dimension) and 24 years (temporal dimension) for each country in the panel. The econometric analysis was carried out using EViews 12 (Student Version). The variables, their definitions, measurement units, and data sources are presented in Table 1.

Table 1. Variable definition, measurement units and data sources

Variable	Definition	Measurement unit	Data sources
Natural gas consumption *(NGC)*	Total natural gas consumption by the country	Terawatt-hour (TWh) equivalents per year	Our World in Data[1]
Natural gas production *(NGP)*	Total natural gas production by the country	Terawatt-hour (TWh) equivalents per year	Our World in Data[2]
Global natural gas price *(NG_PRICE)*	Henry Hub Natural Gas Spot Price	Dollars per Million Btu	U.S. Energy Information Administration
Oil consumption *(OC)*	Total oil consumption by the country	Terawatt-hour (TWh) equivalents per year	Our World in Data[1]
Oil production *(OP)*	Total oil production by the country	Terawatt-hour (TWh) equivalents per year	Our World in Data[2]
Global oil price *(O_PRICE)*	Europe Brent Spot Price FOB	Dollars per Barrel	U.S. Energy Information Administration
GDP per capita *(GDP_CAP)*	GDP divided by midyear population	GDP per capita in constant LCU	World Bank Database
Imports *(IMP)*	Total imports of goods and services	% of GDP	World Bank Database
Exports *(EXP)*	Total exports of goods and services	% of GDP	World Bank Database
Industrialization *(IND)*	Industry (including construction), value added	% of GDP	World Bank Database
Urbanization *(URB)*	Urban population	% of total population	World Bank Database

Note: [1]Our World in Data based on Statistical Review of World Energy: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (Accessed on 10 January 2023). [2]Our World in Data based on BP Statistical Review of World Energy; The Shift Dataportal: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html;https://www.theshiftdataportal.org/energy (Accessed on 10 January 2023).
Source: Authors' work.

2.2. Methodological steps

From this perspective, in the estimation of long-run coefficients we use the Fully Modified Ordinary Least Square (FMOLS) Model, where natural gas consumption (NGC) and oil consumption (OC) are the dependent variables, while natural gas production (NGP), oil production (OP), global natural gas price (NG_PRICE), global oil price (O_PRICE), GDP per capita (GDP_CAP), imports (IMP), exports (EXP), industrialisation (IND), and urbanisation (URB) are the control or explanatory variables. In this sense, our first step is to test the stationarity hypothesis for each variable used and included in the panel analysis.

The stationarity was tested by the Levin-Lin- Chu, Im-Pesaran-Shin, ADF-Fisher and PP-Fisher tests, with the null hypothesis of the existence of a unit root. Furthermore, another important aspect was to test for the presence of cointegration effects in the panel variables. In this regard, we opted for the application of the Kao Cointegration Test.

Given that the variables are cointegrated (see Table 3), the next step was to determine the long-run relationships between the variables. In this respect, the method applied is the FMOLS Model. The FMOLS Regression is used to estimate the regression coefficients of a panel regression model. FMOLS models are categories of multiple time series models that directly estimate the long-run effect of the independent variables on the dependent variables after correcting for the endogeneity problem in the time series. The pooled FMOLS estimation with heterogenous long-run coefficients for first-stage residuals and long-run covariance estimates calculated using the Bartlett kernel and Newey–West fixed bandwidth was applied to the Equation (3) and Equation (4).

$$NGC_{it} = \alpha_{it} + \beta_1 NGP_{it} + \beta_2 NG_{PRICE_{it}} + \beta_3 GDP_{CAP_{it}} + \beta_4 IMP_{it} + \beta_5 EXP_{it} + \beta_6 IND_{it} + \beta_7 URB_{it} \quad \textbf{(3)}$$

$$OC_{it} = \alpha_{it} + \beta_1 OP_{it} + \beta_2 O_{PRICE_{it}} + \beta_3 GDP_{CAP_{it}} + \beta_4 IMP_{it} + \beta_5 EXP_{it} + \beta_6 IND_{it} + \beta_7 URB_{it} + \varepsilon_{it} \quad \textbf{(4)}$$

Where: α_{it} = the overall constant of the model that captures the effects of those variables that are constant over time; β_{it} = the estimated coefficients; ε_{it} = the error terms; i = country, and t = time.

Therefore, the next methodological aspect is to assess short-term and long-term relationships between the natural gas consumption (NGC) and the oil consumption (OC) and the rest of the used variables. Hence, if I(1) variables are cointegrated, that means the variables have a log-run relationship and we can successfully perform and run the VEC panel model to examine both short-run and long-run dynamics. The general form of the VAR model is presented in the equation (5).

$$\Delta Y_t = \sigma + \sum_{i=1}^{k-1} \gamma_i \Delta Y_{t-i} + \sum_{j=1}^{k-1} \eta_j \Delta X_{t-j} + \sum_{m=1}^{k-1} \xi_m \Delta R_{t-m} + \lambda_i ECT_{t-1} + \mu_t \quad \textbf{(5)}$$

Where: $k-1$ is the lag length is reduced by 1; Y and X designate the dependent and independent variables; γ_i; η_j; ξ_m represent short-run dynamic coefficient of the model's adjustment long-run equilibrium; ECT_{t-1} indicates the lagged OLS residual obtained from the long-run cointegration equation: $Y_t = \sigma + \eta_j X_t + \xi_m R_t + \mu_t$ and expressed as: $ECT_{t-1} = [Y_{t-1} - \eta_1 X_{t-1} - \xi_1 R_{t-1}]$, the cointegration equation and the ECT explains the previous period's deviation from long-run equilibrium influences short-run movement in the dependent variable; λ_i = coefficient of ECT and the speed of adjustment and μ_t = residuals.

We also apply several causality tests (Dumitrescu and Hurlin, 2012) in order to examine the existence of the uni-and bi-directional relationships between the variables. In this regard, we employ the Dumitrescu-Hurlin Panel Causality Test (2012), under the following hypotheses: H_0: There is no causality relationship between variables; and H_1: There is causality relationship between variables (since p-value is less than 5%, we reject the H_0 and accept H_1).

3. Results and discussion

3.1. Unit root tests and cointegration tests

The stationarity in the time series data is a precondition for the implementation of the FMOLS Model and the vector autoregressive (VAR/VEC) Models, and thus it is checked with panel unit root tests. The results of the unit root tests with panel data are presented in Table 2 and the hypotheses are as follows: the null hypothesis (H_0): The series is non-stationary or the series has a unit root; respectively, the alternative hypothesis (H_1): The series is stationary, or the series has no unit root. The five tests applied (i.e. Levin, Lin and Chu, Im, Pesaran and Shin, ADF-Fisher, and PP-Fisher Tests) indicate that all variables are stationary with an extremely high level of probability (p-value is less than 0.001).

Table 2. Panel unit root tests results

Variable	Levin, Lin & Chu		Im, Pesaran& Shin		ADF-Fisher		PP-Fisher	
	Level	Diff.	Level	Diff.	Level	Diff.	Level	Diff.
NGC	-1.39	-7.30*	-1.55	-6.51*	14.88	56.95*	15.81	94.71
NG_ PRICE	-2.81*	-11.09*	-1.22	-10.23*	13.16	80.98*	11.71	82.66*
NGP	0.80	-6.72*	-0.06	-5.78*	15.44	47.75*	9.89	52.71*
OC	-1.42***	-7.69*	-1.58***	-7.08*	17.01***	57.08*	12.64	72.65*
O_PRICE	-0.65	-6.96*	1.009	-5.34*	3.84	41.67*	4.24	40.84
OP	0.02	1.81	0.88	-2.14**	10.11	22.7**	2.22	39.92*
GDP_CAP	-0.69	-2.40*	1.84	-2.77*	4.61	25.51*	1.37	56.85*
EXP	-1.49***	-10.10*	-0.97	-9.04*	17.04***	71.47*	23.91*	253.1*
IMP	-0.88	-3.26*	-0.82	-4.45*	12.79	35.83*	8.97	161.1*
IND	-0.55	-5.87*	0.82	-5.08*	5.90	40.77*	10.28	47.09*
URB	-0.93	3.65	3.91	-2.24**	4.84	27.12*	0.54	29.07*
Results	**I (1)**							

Note: These tests are including individual intercept and linear trend at the level and the first difference. * indicates 1% significance level; ** indicate 5% significance level; *** indicate 10% significance level. Source: Authors' work using EViews 12.

Moving forward, the next step we performed was to test the hypothesis of cointegration or the existence of a long-term relationship at the level of the variables included in the two panels, i.e. natural gas variables, and oil variables. For this purpose, we applied the Kao Residual Cointegration Test, often used to test long-term relationships between variables, with the following hypotheses: the null hypothesis (H0) proposed that there is no cointegration between the variables, while the alternative hypothesis (H1) is that all variables are cointegrated.

Table 3. The results of Kao Residual Co-integration Test

Natural gas variables	t-statistic	-2.545583
	Prob.	(0.0055)
Oil variables	t-statistic	-2.901278
	Prob.	(0.0019)

Note: In the brackets is p-value. *Source:* Authors' work using EViews 12.

The results presented in Table 3 statistically affirm the presence of the long-run relationship between variables, thus the variables co-integrated one another (the statistical results show the p-value of natural gas variables is 0.0055, in case of oil variables is 0.0019, both of them are less than 5%, and H0 is rejected).

3.2. Results from FMOLS Regression

Hence, Panel Cointegration Method (FMOLS Model) and Vector Error Correction Model (VECM) are the relevant and suitable econometric methods to be applied as means of the data analysis. We start by showing the long-run relationships among the proposed variables in our panels: the natural gas variables and the oil variables. Table 4 shows the results obtained from the FMOLS econometric methods, using natural gas consumption (NGC) as the dependent variable.

Table 4. The results of panel co-integration (FMOLS) Model
Natural gas consumption as a dependent variable

Independent variables	NGP	NG_PRICE	GDP_CAP	EXP	IMP	IND	URB
Coefficient	0.776*	0.1017*	-1.76e-06	-0.928*	-0.030	-0.152*	1.1593*
R^2	0.92						
Adj. R^2	0.91						
Normality test	0.4179 (0.8114)						

Note: * indicates 1% significance level. The p-value of normality test is in brackets. Source: Authors' work using EViews 12.

Our first observation is that there is a positive and direct long-run relationship between natural gas consumption (NGC) and the global natural gas price (NG_PRICE); for a 1% rise in NG_PRICE, the NGC increases in the long run by about 0.10%. It confirms that any change in the global natural gas price has an impact on the evolution of natural gas consumption for the Caspian region, which is maintained in the long run. Moreover, these aspects have also been confirmed in other previous research (Jahangir and Dural, 2018; Magazzino, 2016; Ozturk and Al-Mulali, 2015), where the authors concluded that in the long term the relationship between the global gas price and domestic natural gas consumption is maintained. The estimation and prediction of natural gas consumption must take into account the dynamics in the global natural gas price level (which is increasingly volatile and fluctuating nowadays).The long-term relationship between natural gas consumption (NGC) and natural gas production (NGP) is also confirmed, with a positive and direct impact on NGC of about 0.78%. Interestingly, the level of natural gas consumption (NGC) is supported in the long term by the positive and direct effects of urbanisation (URB); it increases by approximately 1.16%. Even if this was expected, we consider that the long-term population growth rate and the migration of the population from rural to urban areas leads to future challenges for the regulators and policy-makers in order to optimise domestic gas production by new modern exploitation techniques, attracting investments or establishing commercial energy partnerships (Apergis and Payne, 2010; Bilgili et al., 2016).

It is also important for the Caspian countries to resolve their environmental/political system instability challenges/issues/problems, since many studies show that energy security in these countries can be significantly improved, especially through a better correlation between economic policies and energy policies. At the same time, we identify a downward trend in natural gas consumption in the long term, which is surprised by the fact that all coefficients' signs for exports (EXP) and industrialisation (IND) are negative, leading us to expect that the Caspian countries will steadily and intensively improve their priorities related to the exploration, production, and transportation of their energy resources.

Furthermore, the panel FMOLS Model is robust and appropriate to identify the long-run relationships between the variables; and the natural gas consumption is highly explained by the explanatory variables used, with approximately 91% (according to the results of Adj. R^2). At the same time, the results of the Jarque-Bera test informs us that the model is correctly performed, the variance of the residuals is constant over the time and the error terms are normally distributed.

Table 5. The results of panel co-integration (FMOLS) Model
Oil consumption as a dependent variable

Independent variables	OP	O_PRICE	GDP_CAP	EXP	IMP	IND	URB
Coefficient	0.644*	-0.020	0.017*	-1.122*	0.198*	-0.273**	1.2999*
R^2	0.92						
Adj. R^2	0.91						
Normality test	0.6922 (0.7074)						

Note: * indicates 1% significance level. The p-value of normality test is in brackets. Source: Authors' work using EViews 12.

On the same note, long-term relationships on the variables in the second panel (i.e., oil variables) were examined applying the panel cointegration (FMOLS regression) model. The results showed that oil consumption (OC) is positively and directly influenced by both oil production (OP), GDP per capita, imports (IMP), and urbanisation (URB) in the long run. Thus, we find that while oil production (OP) increases by 1%, oil consumption (OC) also increases by about 0.65% in the long run.

In contrast to the findings for gas consumption (NGC), we note that in the long run oil consumption is positively influenced by GDP per capita (GDP_CAP) and imports (IMP), with an increasing trend of 0.02% and 0.20%, respectively. Thus, the economic growth hypothesis is validated, which means that oil plays a vital role for overall economic activity within the five Caspian countries, and generates economic growth and economic welfare (Jahangir and Dural, 2018; Noorollahi et al., 2021). With the exception of the global oil price (O_PRICE), which has a marginal and slight/limited effect on oil consumption in the long run, the rest of the coefficients obtained are statistically significant at the 1% level of confidence.

In this way, we find that each independent variable has a distinctive and individual impact on oil consumption in the five Caspian countries. Similar to the results for the first panel (i.e., natural gas variables), industrialisation (IND) also generates a decline in oil consumption (OC) up to 27%, indicating a long-term negative and indirect relationship between these variables. Thus, the reduction of oil and natural gas consumption is beneficial in the long term, given the tendency to build up and use various clean and renewable energy resources, supported by the development of the green industries or based on the green technologies (Balitskiy et al., 2016; Bilgili et al., 2016; Kum et al., 2012; Pirlogea and Cicea, 2012).

Urbanisation (URB) also plays a major role in optimising and enhancing the efficiency of Caspian energy resources production, by increasing the use of natural gas and oil on average by up to 1.20% in the long term, and the FMOLS regression was an important tool for identifying the long-run relationships between exogenous variables on oil consumption. For example, the high value of the determination coefficient (Adj. R^2) shows that oil consumption is more than 90% explained by oil production (OP), global oil price (O_PRICE), GDP per capita (GDP_CAP), exports (EXP), imports (IMP), industrialisation(IND), and urbanisation (URB). Furthermore, the Jarque-Bera test demonstrates that the model is correctly specified, the errors are normally distributed, and serial correlation is not present in the residuals series. These findings are presented in Table 5.

3.3. Long- and short-run coefficients from Vector Error Correction Model

The next step was to implement the Vector Error Correction Model (VECM) in both panels (i.e. natural gas variables and oil variables) in order to determine the short and long term relationships between the variables. In this regard, we opted for 2 lags as the optimal lag length for natural gas and oil panels in order not to lose data or information. Moreover, we note that it is recommended to use the VEC Model in the analysis of short- and long-term impacts between energy consumption – economic growth – trade balance – industrialisation and urbanisation, since the variables are stationary at the first difference - I(1).

Table 6. The VECM results for natural gas variables

	Endogenous variables (t)							
Exogenous Variables ($t-1$)	***NGC***	***NG_ PRICE***	***NP***	***GDP_ CAP***	***EXP***	***IMP***	***IND***	***URB***
ECT	-0.06**	-0.10	0.035	0.0012	-0.100*	0.1009*	0.020	-0.0008*
NGC	-0.26*	-0.06	0.104	0.0005	0.050	-0.096	-0.028	0.000497
NG_PRICE	0.04	-0.32*	-0.051	-0.018	-0.067	-0.045	-0.040	-0.00018
NP	-0.14	0.21	0.259*	-0.05***	0.039	0.033	-0.010	4.85e-05
	Endogenous variables (t)							
Exogenous Variables ($t-1$)	***NGC***	***NG_ PRICE***	***NP***	***GDP_ CAP***	***EXP***	***IMP***	***IND***	***URB***
GDP_CAP	0.09	0.06	0.562*	0.665*	0.270	-0.697**	0.081	0.00046
EXP	0.15	0.35	-0.005	0.052	0.228	-0.160	0.033	0.0018*
IMP	0.04	0.05	-0.135**	-0.025	-0.004	0.196**	0.041	-0.0003
IND	-0.03	-0.26	-0.35***	-0.028	-0.128	0.761*	0.048	-0.0005
URB	-4.29**	-24.83	11.377***	-0.475	-21.7**	21.03***	3.79	0.767*

Note: The endogenous and exogenous variables are expressed in logarithmic and differentiated (I1) form. * indicates 1% significance level; ** indicate 5% significance level; *** indicate 10% significance level. In the brackets are presented the p-values for LM and JB Tests. Source: Authors' work using EViews 12.

Table 6 shows the results following the application of the VEC Model in the panel that includes the natural gas variables. The first aspect we look at is that the error correction terms (ECTt-1) are statistically significant at least 5% level of confidence for natural gas consumption (NGC), exports (EXP), imports (IMP), and urbanisation (URB). Specifically, it suggests that the previous periods' deviation from the long-run equilibrium is corrected in the current period with an adjustment speed of 6.6% for natural gas consumption NGC (negative effect); 10% for exports (negative effect); while the speed of adjustment in the case of urbanisation is also negative and much lower approx. 0.08%. The positive effect on imports is an attractive aspect, in this case, the previous periods 'deviation is corrected with 10.09% speed of adjustment.

Table 7. The VECM results for oil variables

Exogenous variables $(t-1)$	Endogenous variables (t)							
	OC	*O_PRICE*	*OP*	*GDP_CAP*	*EXP*	*IMP*	*IND*	*URB*
ECT	-0.002	-0.019*	-0.0006	-0.002**	-0.01*	0.010*	8.98e-05	-8.56e-05*
OC	0.048	-0.074	0.010	0.001	-0.017	-0.096	-0.052	-0.0001
O_PRICE	0.074***	0.046	-0.106*	-0.010	-0.0005	-0.084	-0.061	6.14e-05
OP	0.105	0.469	0.155	0.043	0.172	-0.193	0.032	0.0006
GDP_CAP	-0.522**	-0.635	0.623*	0.567*	-0.196	-0.182	0.107	-0.002***
EXP	-0.184**	0.064	0.113***	0.052	0.171	-0.030	0.099	0.001*
IMP	0.045	-0.123	-0.059	-0.006	0.007	0.170***	0.041	-0.0003
IND	0.226	0.366	0.068	-0.041	-0.171	0.733*	0.018	-0.0002
URB	-5.978	-41.322**	-4.454	-5.399**	-29.4*	22.06*	-0.422	0.763*

Note: The endogenous and exogenous variables are expressed in logarithmic and differentiated (I1) form. * indicates 1% significance level; ** indicate 5% significance level; *** indicate 10% significance level. In the brackets are presented the p-values for LM and JB Tests. Source: Authors' work using EViews 12.

For the oil variables panel (Table 7), we indicate that the error correction terms are negative and statistically significant at least 5% level for the global oil price (the speed of adjustment is 1.9%), for the level of GDP per capita (the speed of adjustment is 0.2%), respectively, for the exports (the speed of adjustment is 1.3%). At the same time, we notice the positive speed of adjustment in the case of imports, with a correction value of only 1%. Interestingly, on urbanisation (URB), the speed of adjustment is very low, so we can say that it is hardly felt and there is no significant deviation from the long-run equilibrium.

Next, we will focus on the analysis of the short-run effects between the variables, according to the output of VEC Model for our two panels. For natural gas variables (results are presented in Table 6), we find that the natural gas consumption (NGC) is statistically associated with a 0.26% decrease in itself in the previous period, which indicates a positive thing for the Caspian countries by initiating the process of using clean and renewable energy resources under the current conditions of fostering a clean environment. This validates the energy conservation hypothesis, whose primary objective translates into a massive decrease in carbon emissions without harming the economic growth (Apergis and Payne, 2010; Bilgili et al., 2016). Surprisingly, the results showed thata1% change in urbanisation (URB) is associated with a 4.3% decrease, on average, in natural gas consumption (NGC) in the short run, which can be explained by the negative effects of the current energy crisis as well as how individuals are more parsimonious and careful about their consumption.

In the case of oil variables (results are presented in Table 7), we highlight that a 1% change in global oil price (O_PRICE) is associated with a 0.07% increase in OC in the short run, meaning that the previous level of the global oil price affects the current consumption of oil within the Caspian states. Again, this is often validated and confirmed in empirical studies in the field of energy resource consumption forecasting (Abumunshar et al., 2020; Akinsola and Odhiambo, 2020; Apergis and Payne, 2010; Chu, 2012). For example, the economic growth is one of the biggest factors affecting petroleum product—and therefore crude oil—demand.

Another aspect that resulted from the analysis of short-term effects for the oil variables suggests that a 1% change in exports (EXP) generates a negative impact on the oil consumption (OC), which decreases by about 0.19%, while the level of GDP per capita (GDP_CAP) reports a 0.55% decrease in the oil consumption. This evidence indicates that the Caspian countries are increasingly concerned about diversifying their export options, which will improve their regional energy security in the future. Also, boosting the production of oil and the extraction of this energy resource is expected to have favourable effects in terms of economic growth and economic development (Hughes and Lipscy, 2013; Jahangir and Dural, 2018).

At the same time, other findings have resulted from the short-term estimation of the coefficients in the two panels, namely: the gas production is positively and directly influenced by the level of GDP per capita (0.56% increase) and the urbanisation (also an increase of 11.38%), while imports and industrialisation cause a decrease in gas production in the current period (i.e. 0.14% for IMP vs. 0.36% for IND). More specifically, these results draw our attention to the positive effects of natural gas for the entire economic activity within the Caspian countries. However, the efforts of the governmental authorities are becoming more pronounced under the current unpredictable context of energy resource management and systematic improvement of the energy sector (all of which are associated with the evolution of the demand for energy resources for each Caspian country).

We also note that a 1% change in oil production generates an increase of about 0.26% in the current period, which is extremely beneficial in terms of improving energy security, that has positive externalities that lead to higher performance and development of the energy sector for each country analysed. Similarly, the oil production provides a boost to economic activity in these countries, which is confirmed by the increase in GDP/capita by almost 0.62% (Chu, 2012; Narayan and Smyth, 2007). Most interestingly, the global oil price has a significant impact on the evolution of oil production, negatively affecting it on average by around 0.10% (Abumunshar et al., 2020; Aimer and Hamoudi, 2018). In the short run, the exports generate an increase of approx. 0.11% on oil production, for which we deduce that their exports are relevant factors that stimulate the economic growth and its development in the examined countries.

3.4. Causality analysis

Finally, we aim to determine the causal relationships between the variables used in the two panels. In this respect, we employ the panel causality test, which was performed using 1 lag as the optimal number for our panel VEC models.

Table 8. The panel causality test results for natural gas variables

Variable	NGC	NGP	NG_PRICE	GDP_CAP	EXP	IMP	IND	URB
NGC	-	2.80**	2.19	2.64**	6.22*	1.48	2.21	1.65
NGP	2.84**	-	2.12	5.04*	4.62*	3.71*	3.19*	3.76*
NG_PRICE	0.72	2.54***	-	4.09*	1.20	1.95	0.95	1.94
GDP_CAP	7.60 *	2.38***	2.40***	-	12.11*	5.96*	2.77**	7.42*
EXP	0.75	2.68**	0.87	4.40*	-	3.54*	1.99	2.11
IMP	2.48***	1.36	2.53***	2.18	6.87*	-	2.24	10.53*
IND	1.11	1.66	3.19*	4.13*	1.12	2.07	-	4.68*
URB	8.54*	4.47*	2.42***	0.98	5.05*	2.12	3.36*	-

Note: The table presents the values of the W-stat for the Dumitrescu-Hurlin Panel Causality Tests. * denotes the statistical significance at 1% p-value; ** denote the statistical significance at the 5% p-value, while *** denote the statistical significance at the 10% p-value. Source: Authors' work using EViews 12.

Table 9. The panel causality test results for oil variables

Variable	OC	OP	O_PRICE	GDP_CAP	EXP	IMP	IND	URB
OC	-	0.65	0.63	3.12*	5.50*	2.0006	3.003**	3.31*
OP	4.73*	-	0.96	4.69*	9.60*	6.58*	1.33	3.38*
O_PRICE	0.89	1.12	-	2.34	8.43*	3.98*	6.80*	2.36
GDP_CAP	3.92*	0.10	1.007	-	12.11*	5.96*	2.77**	7.42*
EXP	3.10*	2.33	0.78	4.40*	-	3.54*	1.99	2.11
IMP	2.34	1.27	0.52	2.18	6.87*	-	2.24	10.53*
IND	1.93	4.20*	1.08	4.13*	1.12	2.07	-	4.68*
URB	1.92	0.84	0.02	0.98	5.05*	2.12	3.36*	-

Note: The table presents the values of the W-stat for the Dumitrescu-Hurlin Panel Causality Tests. * denotes the statistical significance at 1% p-value; ** denote the statistical significance at the 5% p-value, while *** denote the statistical significance at the 10% p-value. Source: Authors' work using EViews 12.

Table 8 shows the results for the natural gas variables, while Table 9 shows the results for the oil variables. Thus, we identify a bidirectional causality relationship between natural gas consumption (NGC) and natural gas production (NGP); natural gas consumption (NGC), and GDP per capita (GDP_CAP), as well as the bidirectional relationship between natural gas production (NGP) and GDP per capita (GDP_CAP).

These causal relationships in both directions show that the energy sector has a considerable contribution to the economic activity in the Caspian countries; at the same time, the growth hypothesis holds in these countries. Moreover, there is a unidirectional relationship between natural gas consumption (NGC) and exports (EXP); a bidirectional relationship is confirmed between natural gas production (NGP) and exports (EXP), both of them suggesting that the change in exports produces an increase in domestic gas consumption and domestic gas production. Our findings are in line with the other studies conducted by Ighodaro (2010); Kalyoncu et al. (2013); which examines the various relationships between energy consumption-energy production-economic growth.

The natural gas consumption is caused by the imports volume, which is proven by the presence of a statistically significant unidirectional relationship at the 10% level. The same is captured in the case of urbanisation; the unidirectional causal relationship from urbanisation (URB) to natural gas consumption (NGC) essentially shows that the more migration persists and the population increases, the more natural gas consumption is stimulated. Also, the global natural gas price (NG_PRICE) produces effects on the Caspian gas production (NGP), which is confirmed by the presence of the unidirectional relationship. We confirm the presence of bidirectional causality relationships between industrialisation (IND) and GDP per capita (GDP_CAP); industrialisation (IND) and urbanisation (URB), favourable to support the long-term economic growth driven by the focus on the education, training, and motivation of the employment (especially in the extractive and production industries of the Caspian energy resources).

Other bidirectional causal relationships are found between oil consumption (OC) and GDP per capita (GDP_CAP); oil consumption (OC) and exports (EXP), all of which indicate the vital role of oil in underpinning and continuously supporting the efficiency of the energy sector within the Caspian countries. Also, unidirectional relationships between oil consumption (OC) and industrialisation (IND), oil consumption (OC) and urbanisation (URB), oil production (OP) and exports (EXP) and oil production (OP) and urbanisation (URB) have been highlighted by applying the Dumitrescu-Hurlin panel causality test. Thus, we can conclude that Caspian energy resources (crude oil and natural gas) hold an increased importance in terms of energy trade expansion, diversification of export routes, and the enlargement of regional cooperation (especially within European countries).At the same time, these competitive advantages can be maintained in the long term by establishing new directions and policies that encourage the use and production of these energy resources, as well as by dealing with policy issues that can disrupt the proper performance of the entire energy system in the Caspian countries. Moreover, natural gas and crude oil are the main inputs for many other sectors, including the need to attract new investments and projects to support economic growth.

Hence, we do not ignore that these countries present several politically connected threats, so that Caspian energy security can be established according to a persistent and thorough analysis of the causal relationships between energy consumption-economy growth-trade (in terms of exports and imports). Essentially, we are convinced that the improvement of energy security in this region is mainly regarded from the security of demand and as well as security of energy transportation and energy supply, where the four specific aspects that must be achieved are: availability, affordability, accessibility, and acceptability.

4. Conclusions

The main findings of our research have shown the positive and significant impact of the consumption of the energy resources (oil and natural gas) on the gradual increase in the production of these energy resources, resulting in the development of the economic activity in the Caspian countries. Similar to other research (Chu, 2012; Ighodaro, 2010; Jahangir and Dural, 2018; Kum et al., 2012; Kalyoncu et al., 2013)**,** the growth, conservation, and feedback hypotheses were supported by our analysis, explaining why the existence of one-way causal/unidirectional relationships between energy consumption and economic growth shows that the primary energy consumption helps to maintain economic growth and the energy conservation policies may be jeopardised. Other aspects that resulted from the analysis suggested that industrialisation and urbanisation are positively causing in only one direction the natural gas consumption and the crude oil consumption, which in the future will systematically lead to an increase in the production of these traditional energy resources, and also to the development of a tendency of using and consuming derived energy resources from renewable sources. We believe that this is viable and will have positive effects on the path of economic growth. At the same time, we should not forget that the Caspian countries are part of the Commonwealth of Independent States (an organisation created by the ex-Soviet countries), where Russia's control is still present and decisive in the control of energy resources, as well as the fact that they are still facing internal problems that can lead to the destabilisation of their economies.

On the other hand, we underline several implications for improving the energy security in this region and implicitly for future directions that can generate positive externalities in terms of growth and economic welfare.

In the first instance, the policymakers in these countries that are intensive in exploration and production the energy (especially, natural gas and crude oil) should promote incentive pricing for a successful energy efficiency plan. In the same vein, packages of measures including financial incentives and regulations should be implemented simultaneously, rather than one after the other. Secondly, we believe that attracting foreign direct investment (FDI) is an important and crucial step towards establishing new access and production routes for the Caspian energy resources (natural gas and crude oil), which in the long term can make a decisive contribution to the importance of the Caspian countries in the global energy markets.

A third aspect refers to the increasing trend in favour of the diversification of export opportunities, as the Caspian countries are seeking to improve cooperation with net importers of energy resources (i.e.,European countries). At the same time, the establishment and formation of mutually beneficial partnerships and trade agreements can be a solution when it comes to improving energy security (Emadi and Nezhad, 2011; VedadiKalanter et al., 2021). Thus, the "win-win" game between the Caspian countries and the European countries can be achieved; the Caspian countries should offer energy resources in exchange for fair tariffs, while the European countries (or the European Union) should show their interest in long-term cooperation (also through investment and technological contributions) - necessary conditions for achieving the highest level of energy security.

In general, the analysis conducted in this study was directed on how the consumption of energy commodities (natural gas and crude oil) has short- and long-term causality relationships on the performance of energy sector (exploration and production of energy resources), the dynamics of global prices, the economic growth (GDP per capita), the industrialisation, the trade openness (exports and imports of these commodities), and the urbanisation within the Caspian countries. A future direction of this study would be to assess the causal relationships between energy consumption and economic growth by increasing the number of energy producing and exporting countries, as well as the extension of the time series used.

In this sense, the aspects that we will respect in further studies are the incorporation of other explanatory variables (i.e. CO_2 Emissions, coal consumption, coal prices, gas reserves, oil reserves, inflation rate, unemployment rate etc.) and the application of other advanced econometric techniques (i.e., machine learning tools).

REFERENCES

[1] **Abumunshar, M., Aga, M., Samour, A. (2020)**, ***Oil Price, Energy Consumption, and CO_2 Emissions in Turkey. New Evidence from a Bootstrap ARDL Test***. *Energies*, *13*(21), 5588;

[2] **Aimer, N., Hamoudi, M.E. (2018),** ***Investigation of effect of crude oil consumption on economic growth in oil exporting countries: Panel data analysis.*** *International Journal of Latest Research in Humanities and Social Science*, *1*(3), 06-14;

[3] **Akinsola, M.O., Odhiambo, N.M. (2020),** ***Asymmetric effect of oil price on economic growth: Panel analysis of low-income oil-importing countries.*** *Energy Reports*, *6*, 1057-1066;

[4] **Apergis, N., Payne, J.E. (2010),** ***Natural gas consumption and economic growth: A panel investigation of 67 countries.*** *Applied Energy*, *87*(8), 2759-2763;

[5] **Balitskiy, S., Bilan, Y., Strielkowski, W., Štreimikienė, D. (2016),** ***Energy efficiency and natural gas consumption in the context of economic development in the European Union***. *Renewable and Sustainable Energy Reviews*, *55*, 156-168;

[6] **Beyca, O.F., Ervural, B.C., Tatoglu, E., Ozuyar, P.G., Zaim, S. (2019),** ***Using machine learning tools for forecasting natural gas consumption in the province of Istanbul.*** *Energy Economics*, *80*, 937-949;

[7] **Bilgili, F., Koçak, E., Bulut, Ü. (2016),** ***The dynamic impact of renewable energy consumption on CO_2 emissions: A revisited Environmental Kuznets Curve approach.*** *Renewable and Sustainable Energy Reviews*,*54*, 838-845;

[8] **Chu, H.-P. (2012),** ***Oil consumption and output: What causes what? Bootstrap panel causality for 49 countries***. *Energy Policy*, *51*, 907-915;

[9] **Das, D., Srinivasan, R., Dhankar, R. (2014),** ***Petroleum Oil Consumption in Major Countries of the World: A Panel Data Analysis.*** *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *36*(23), 2635-2644;

[10] **Destek, M.A. (2016),** ***Natural gas consumption and economic growth: Panel evidence from OECD countries.*** *Energy*, *114*, 1007-1015;

[11] **Dumitrescu, E.-I., Hurlin, C. (2012), *Testing for Granger non-causality in heterogeneous panels.*** *Economic Modelling*, *29*(4), 1450-1460;

[12] **Emadi, S.E., Nezhad, H. (2011), *Energy market for Caspian Sea oil and its supply.*** *IBSI Scientific Journal*, *5*(2), 21-34;

[13] **Hughes, L., Lipscy, P.Y. (2013), *The Politics of Energy.*** *Annual Review of Political Science*, (16), 449-469;

[14] **Ighodaro, C.A. (2010), *Co- integration and causality relationship between energy consumption and economic growth: Further empirical evidence for Nigeria.*** *Journal of Business Economics and Management*, *11*(1), 97-111;

[15] **Izanloo, M., Noorollahi, Y., Aslani, A. (2021), *Future energy planning to maximize renewable energy share for the south Caspian Sea climate.*** *Renewable Energy*, *175*, 660-675;

[16] **Jahangir, S.M., Dural, B.Y. (2018), *Crude oil, natural gas, and economic growth:impact and causality analysis in Caspian Sea region.*** *International Journal of Management and Economics*, *54*(3), 169–184;

[17] **Kalyoncu, H., Gürsoy, F., Gocen, H. (2013), *Causality Relationship between GDP and Energy Consumption in Georgia, Azerbaijan and Armenia.*** *International Journal of Energy Economics and Policy*, *3*(1), 111-117;

[18] **Kaplan, M., Ozturk, I., Kalyoncu, H. (2011), *Energy Consumption and Economic Growth in Turkey: Co-integration and Causality Analysis.*** *Romanian Journal of Economic Forecasting*, *14*(2), 31-41;

[19] **Kum, H., Ocal, O., Aslan, A. (2012), *The relationship among natural gas energy consumption, capital and economic growth: Bootstrap-corrected causality tests from G-7 countries.*** *Renewable and Sustainable Energy Reviews*, *16*(5), 2361-2365;

[20] **Magazzino, C. (2016), *The Relationship among Real Gross Domestic Product, CO_2 Emissions, and Energy use in South Caucasus and Turkey.*** *International Journal of Energy Economics and Policy*, *6*(4), 672-683;

[21] **Narayan, P.K., Smyth, R. (2007). *A panel cointegration analysis of the demand for oil in the Middle East.*** *Energy Policy*,*35*(12), 6258-6265;

[22] **Noorollahi, Y., Janalizadeh, H., Yousefi, H., Jahangir, M.H. (2021), *Biofuel for energy self-sufficiency in agricultural sector of Iran.*** *Sustainable Energy Technologies and Assessments*, *44*, 101069;

[23] **Ozturk, I., Al-Mulali, U. (2015), *Natural gas consumption and economic growth nexus: Panel data analysis for GCC countries.*** *Renewable and Sustainable Energy Reviews*, *51*, 998-1003;

[24] **Pirlogea, C., Cicea, C. (2012), *Econometric perspective of the energy consumption and economic growth relation in European Union.*** *Renewable and Sustainable Energy Reviews*, *16*(8), 5718-5726;

[25] **Vedadi Kalanter, S., Maleki, A., Saifoddin, A. (2021), *Study of Caspian energy markets via a hybrid index for energy demand security in Caspian countries in years 2020 and 2030*.** *International Journal of Energy and Water Resources*, *5*, 145–157.