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# A PANEL DATA ANALYSIS IN ESTIMATING THE ECONOMIC GROWTH FOR OIL-PRODUCING COUNTRIES.EVIDENCE FROM THE CASPIAN REGION

***Abstract.*** *The aim of the study is to estimate the economic growth within the Caspian countries (Azerbaijan, Iran, Kazakhstan, Turkmenistan, Russia, and Uzbekistan) in the period 1997- 2018 by applying panel methodological approach. From this perspective, two econometric models were created in which we investigated the impact of the explanatory variables (i.e. Brent Crude Oil Price, Exports, Imports, Government Expenditure, Foreign Direct Investments, and CO2 Emissions) on economic growth expressed according to the level of GDP per capita in these oil-producing Caspian countries. The economic growth in the Caspian countries was measured and estimated using specified panel regression methods, such as: the Common Effects Model, the Fixed Effects Model, and the Random Effects Model. The obtained results showed that GDP per capita is positively and directly influenced, generating a 1.60% increase influenced the Exports, while 10% increase of CO2 Emissions determines approximately 1% decrease of GDP per capita in the analysed period. At the same time, by applying the Vector Error Correction model (VECM), our results showed that the variables are not cointegrated and the level of GDP per capita is not influenced by the co-movements of the explanatory variables in the long-run. Interestingly, the economic growth is not influenced by the Foreign Direct Investments (FDI), which is recommended and indicated for the six Caspian countries to diversify their export opportunities (especially oil and natural gas) in order to the energy security objectives.*

***Keywords****: Economic growth, Energy resources, Caspian region, Panel data analysis, Brent Crude Oil Price, Fixed Effect Model, Random Effect Model, Common Effects Model.*

**JEL Classification: C23, C33, C51, O11, Q40, Q43**



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## 1. Introduction

The fundamental objective of this research is the measurement and estimation of the economic growth within the countries of the Caspian region: Azerbaijan, Iran, Kazakhstan, Russia, Turkmenistan, and Uzbekistan. The motivation of the analysis is suggested by the increased emphasis and high importance assigned to this geographical region, and from this point of view many actual studies show the geopolitical implications and economic potential that are recognized in this Caspian region which is rich in important energy resources. Specifically, the Caspian countries are considered important strategic points in the terms of international trade, emphasizing their quality of net producing and net exporting countries of energy products, especially natural gas and oil.

From this perspective, we consider that it is important to perform an econometric analysis to explain the nexus between economic growth and macroeconomic variables/aggregates in these countries. So, we opted for panel analysis, according to which we can estimate and measure the degree of economic growth (in terms of GDP per capita) under the impact of several explanatory variables, such as: Brent Crude Oil Price, Exports, Imports, Government Expenditure, Foreign Direct Investments, and CO2 Emissions.

Our panel analysis was performed by creating the two models that measure the economic growth in the Caspian countries in the period 1997-2018. In this approach, we used three panel specifications: Common Effect Model (CE or POLS), Fixed Effect Model (FE), as well as the Random Effect Model (RE). Our attention is also drawn to the increased predilection of the empirical researches that investigate the possible causality between GDP per capita and Brent Crude Oil Prices, and how every co-movement of an increase or decrease in the price of oil can affect the economic growth in these rich energy resources countries.

Lim et al (2014) conducted a panel analysis by testing the causality link between the consumption of energy resources and economic growth across 61 countries in the period 1990 to 2008. Applying the Fixed Effect Model and Random Effect Model, the main results showed that the level of consumption of energy can increase up to a certain point, beyond which the level of GDP per capita increases. Moreover, the authors demonstrated that this inverse-U relationship between GDP per capita and oil consumption is explained in terms of the interaction of scale, composition, and technical effects.

The same authors (Lim et al, 2014) investigated the causality relation between oil consumption, the amount of CO2 Emissions and economic growth in the Philippines during the period 1965-2012. By applying a diverse methodology based on cointegration tests, Granger causality and Error Correction Model (ECM Model), results revealed the existence of a bidirectional relation in the long-run between oil consumption and economic growth, as well as between the consumption of oil and CO2 Emissions, which implies that Philippines should diversify and improve oil consumption that does not generate an additional increase in the quantity of CO2 Emissions. The relationship between economic growth and the global oil price within the Caspian countries was investigated by Bolganbayev et al (2021). The results of the study indicated that an increase of oil price by 1% generates 0.70% increase in the economic growth in these analysed countries. The same study highlighted that the level of income in these countries is closely dependent on the exports, thereby the model was focused by explaining the impact of Brent Crude Oil prices in terms of Caspian energy security in the period 2007-2020.

In the same way, Horobeț et al (2021) examined the causality relation between consumption of energy, economic growth, CO2 Emissions, Foreign Direct Investments, and international trade in the 24 EU countries in the period 1995-2018. The results obtained from the panel analysis (panel VECM analysis) showed the unidirectional link between economic growth and the CO2 Emissions. Also, exports, imports and foreign direct investment have a positive and direct impact on the reduction of these CO2 emissions, confirming the EU's long-term objective of promoting an energy policy with a low consumption of these carbon emitters.

On the other hand, Ibrayeva et al (2018) studied the importance of the Caspian countries in achieving and enhancing the energy security at the EU level. Taking into consideration the quality of net imports of energy resources, the EU is increasingly concerned in promoting and establishing the ambitious projects that facilitates the new opportunities for transportation and supply of energy Caspian commodities. Analysing the geopolitical implications, this study highlighted the EU's tendency to remain the only important player in the field of energy security, through its effort to strengthen a solid and viable energy infrastructure, by consolidating the Southern Energy Corridor – a relevant connection between EU and Caspian region.

Lee (2005) was among the first authors that analysed the causality aspects between energy consumption and GDP by using a cointegrated panel analysis. In his methodological approach, the author used data from the 18 developing countries during the period 1975-2001. Granger causality statistical test showed that it is a positive and unidirectional nexus between energy consumption and economic growth in the short-term, which is not applicable in the long-run. At the same time, it was confirmed the followed hypothesis: energy represents the central pillar which leads to sustainable economic growth.

In a similar approach, the study conducted by Rajbhandari and Zangh (2017) showed the existence of a bidirectional causality relation between a lower intensity energy and a higher economic growth rate in the case of developing countries. Applying the panel methodology, the authors demonstrated that the trend of economic growth in the long-run can be supported by the intensification of renewable energy. Also, this aspect was investigated and concluded by Horobeț et al (2021) in his study.

Furthermore, an empirical study by Uçan et al. (2022) examined the relationship between energy consumption and economic growth within the 15 developed countries. The econometric analysis was based on the dynamic panel framework, as well as the application of cointegration and causality tests. Thus, the obtained results highlighted there is a bidirectional causality link between economic growth and energy consumption in the analysed developed countries. Moreover, the results suggested that the economic growth increase almost by 0.20% as a result of the 1% increase in energy consumption in the long term.

At the same time, another study (Campo and Sarmiento, 2013) was focused in testing the relationship between energy consumption and GDP in the case of Latin American countries in the period 1971-2007. In this regard, the authors applied Pedroni and Westerlund causality tests in estimating the slopes of the long-run relationship variables. Consequently, the existence of the causality relation between energy consumption and GDP has been demonstrated, which means that in a prolonged period of time energy generates economic growth for the majority of Latin American countries. Another implication of this empirical research was suggested by the establishment of the energy conservation programs, as well as the need to diversify energy sources to ensure sustainable economic growth in the short and long run.

Kasperowicz (2014) used panel analysis to estimate the possible nexus between energy consumption and economic growth for 12 European countries in the period 2000-2012. Starting from the assumption that there is a positive and direct relationship between these variables, the results showed that the evolution of GDP does not exclusively depend on energy consumption, but rather by other explanatory variables, for example the increase of the Gross Fixed Capital or marginal productivity. A significant link between energy consumption and economic growth was demonstrated in the study conducted by Işik and Shahbaz (2015). The panel methodology was applied within the OECD countries in the period 1980-2010. The main finding according to the econometric results was evidenced by the various energy resources (in particular, natural gas and oil) by finding incentives for investments, as well as by the development of solid access paths of these resources.

Rodriguez-Caballero (2022) proposed an integrated panel model that is able to identify co-movements between several cross-sectional blocks of stationary and non-stationary variables. This flexible model is based on Monte Carlo simulations to investigate the long-term relationship between energy consumption and economic growth in 69 countries in different time periods. The results showed that there is a low and predictable impact between energy consumption and GDP, which it can generate new directions and further assumptions about the efficiency of energy security which can be provided in the future empirical studies.

The paper is organized in the following order: section 2 describes the Research Methodology, Data, and Preliminary Analysis of the time series used section 3 discussed the main results and interpretation of these results and section 4 presents the main conclusion.

**2. Research Methodology**

Our study's the main objective is the analysis of the economic growth of the six Caspian countries (i.e. Azerbaijan, Iran, Kazakhstan, Russia, Turkmenistan, and Uzbekistan) by applying the several panel specifications as Common Effects Model or POLS Model, Fixed Effects Model (FE), respectively, the Random Effects Model (RE). From this point of view, we used two explanatory models in order to measure and estimate degree of economic growth, having the GDP per capita as an important macroeconomic indicator.

The first model (Model 1) analyses the interdependence relation between GDP per capita and 4 independent/explanatory variables (i.e. Brent Crude Oil Prices, Exports, Foreign Direct Investments (FDI), and CO2 Emissions).

The second model (Model 2) aims to investigate the interdependence relation between GDP per capita and Brent Crude Oil Prices, Imports, Foreign Direct Investments (FDI), and Government Expenditure (GOV Expenditure) in these Caspian countries.

The conception of the 2 explanatory models was based on a series of theoretical and empirical different arguments reported in the literature. For example, the level of GDP per capita related to the 6 Caspian countries (the evolution is presented in Figure 1) is directly influenced by the value of exports, taking into account that these countries represent the main producers and exporters of energy resources, especially oil, and natural gas.

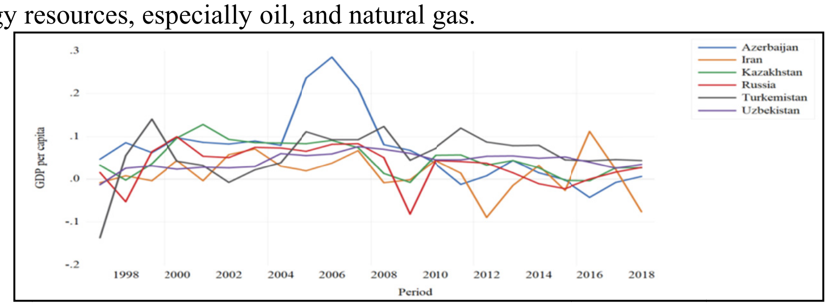


**Figure 1. Evolution of GDP per capita for each country**

From this relevant reason, we considered that it is recommended to include in the 2 models, Brent Crude Oil Prices and Exports, in estimating the GDP per capita/economic growth. Figure 2 shows the current evolution of Brent Crude Oil Prices in the analysed period, i.e. 1997-2018.

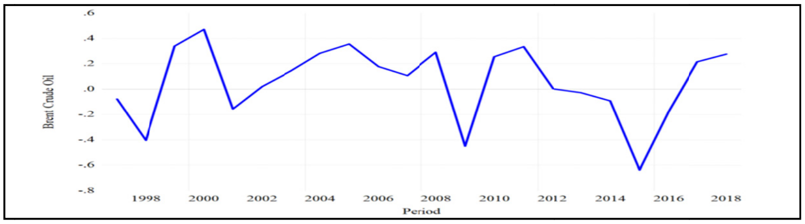


**Figure 2. Evolution of Brent Crude Oil Prices**

The negative effects produced by the Global Financial Crisis of 2008 are observed, according to the prices of the oil (considered more and more a highly traded strategic asset) are increasingly volatile, even registering negative values up to -60% in the international financial and economic context.

Also, the model 1 takes into consideration the level of CO2 Emissions as well as the Foreign Direct Investments (FDI), and is able to observe and investigate if there is a causal relationship between those variables and the current GDP per capita. The level of development of a country or region is influenced by the government's ability to use financial resources in producing or generating a sustainable economic growth. The econometric model 2 takes into account the Government Expenditure as an explanatory variable.

Regarding the commercial opening of a country, it is noted that the Caspian countries have recently intensified energy resources commercial exchanges, and from this perspectives, the level of GDP per capita is more and more influenced in a positive and direct way. Thereby, the model 1 includes the Exports as an explanatory variable, while the model 2 embraces the Imports as an independent variable.

Table 1 shows these explanatory variables introduced in the 2 econometric models and their definitions to estimate the level of economic growth in these six Caspian countries in the period 1997-2018.

**Table 1. Description of explanatory variables**

| Variables | Definition | Measurement unit | Data source | Type of variable in panel regression |
|---|---|---|---|---|
| GDP per capita | GDP per capita in constant 2015 US dollars | US dollars | World Bank | Dependent variable |
| Brent Crude Oil | Europe Brent Spot Price FOB | Dollars per Barrel (USD/bbl) | The U.S. EIA | Independent variable |
| CO2 emissions | Emissions produced within a country without accounting for the trading of goods | Kiloton (kt) | World Bank | Independent variable |
| Exports | Total exports of goods and services | Million US dollars | World Bank | Independent variable |

| | | | | |
|---|---|---|---|---|
| Imports | Total imports of goods and services | Million US dollars | World Bank | Independent variable |
| Government expenditure (GOV Expenditure) | Total government expenditures of goods and services | Million USD | World Bank | Independent variable |
| Foreign direct investment (FDI) | Stock of inward forward direct investments | Billions USD | World Bank | Independent variable |

The source of data is the Database of the World Bank and The U.S. Energy Information Administration. The number of countries included in the panel was 6, i.e. Azerbaijan, Kazakhstan, Iran, Russia, Turkmenistan and Uzbekistan, and the data covers 1997-2018. In total, the number of country-year observation is 132. The panel used for this research is balanced (data for all countries), and fixed (data for all years). All variables have been transformed using the natural logarithm and first difference in the econometric models with the aim of achieving consistent results and a stationary time series.

Table 2 shows the statistical description of these variables used to measure the level of economic growth (GDP per capita) in the surrounding countries at the Caspian Sea. According to these data, the average value of GDP per capita is 0.045, and the standard deviation is approximately 0.054. It is also observed that the FDI have the highest value of standard deviation (0.70), and the second highest value being observed in Brent Crude Oil Prices (0.28). We can conclude that these explanatory variables recorded many fluctuating co-movements in the last period of time, and this generates a high level of risk or volatility.

**Table 2. Descriptive statistics for all variables**

| **Variable** | **GDP per capita** | **Brent Crude Oil Price** | **CO2 emissions** | **Exports** | **Imports** | **GOV Expenditure** | **FDI** |
|---|---|---|---|---|---|---|---|
| **Mean** | 0.0447 | 0.0563 | 0.0147 | 0.08849 | 0.0754 | 0.0765 | 0.0625 |
| **Max.** | 0.2854 | 0.4707 | 0.2044 | 0.8645 | 1.0697 | 0.8614 | 2.3479 |
| **Min.** | -0.136 | -0.637 | -0.2223 | -0.6181 | -0.8339 | -0.5749 | -4.0342 |
| **Std.dev.** | 0.0536 | 0.2844 | 0.0672 | 0.2497 | 0.2148 | 0.2026 | 0.7023 |
| **Skewness** | 0.6684 | 0.8009 | -0.6959 | -0.2317 | -0.0351 | -0.4727 | -1.0141 |
| **Kurtosis** | 7.4554 | 2.8869 | 5.0821 | 3.5691 | 7.4107 | 5.4552 | 11.8245 |
| **Obs.** | 132 | 132 | 132 | 132 | 132 | 132 | 132 |

Regarding the analysis of time series distributions, using the Skewness and the Kurtosis, has been found that Brent Crude Oil Prices, CO2 Emissions, and Government expenditure (GOV Expenditure) have an asymmetry to the left, which means that these data series had downward trends in the analysed period.

Before applying the panel regression methods, we tested the time-series for unit root tests and presented the results in Table 3. We used the common four unit-root tests: Levin-Lin and Chu, Im, Pesaran and Shin W-Stat, ADF-Fisher Chi Square and PP-Fisher Chi-Square. According to the results of these tests, all the time series used in the models are stationary with high significance (p-value is 0.0000).

**Table 3. Unit Root Tests for all variables**

| **Variable** | **GDP per capita** | | **Brent Crude Oil** | | **CO2 emissions** | | **Exports** | |
|---|---|---|---|---|---|---|---|---|
| Tests | **Stat.** | **Prob.** | **Stat.** | **Prob.** | **Stat.** | **Prob.** | **Stat.** | **Prob.** |
| Levin, Lin &Chu t* | -4.9327* | 0.0000 | -7.7640* | 0.0000 | -9.1498* | 0.0000 | -7.1412* | 0.0000 |
| Im, Pesaran and Shin W-stat | -4.9124* | 0.0000 | -6.1334* | 0.0000 | -8.7756* | 0.0242 | -5.4371* | 0.0000 |
| ADF-Fisher Chi-Square | 47.4993* | 0.0000 | 56.0922* | 0.0000 | 82.7420* | 0.0298 | 49.5460* | 0.0000 |
| PP-Fisher Chi-Square | 44.1248* | 0.0000 | 54.1506* | 0.0000 | 85.9656* | 0.0160 | 49.3639* | 0.0000 |
| Variable | **Imports** | | **GOV Expenditure** | | **FDI** | | | |
| Tests | **Stat.** | **Prob.** | **Stat.** | **Prob.** | **Stat.** | **Prob.** | | |
| Levin, Lin &Chu t* | -4.3239* | 0.0000 | -1.6128 | 0.0534** | -5.2935* | 0.0000 | | |
| Im, Pesaran and Shin W-stat | -3.6370* | 0.0001 | -2.9488 | 0.0016* | -5.0066* | 0.0000 | | |
| ADF-Fisher Chi Square | 33.7250* | 0.0000 | 27.5290 | 0.0065 | 48.3941* | 0.0000 | | |
| PP-Fisher Chi-Square | 33.4565* | 0.0000 | 47.1890 | 0.0000 | 51.4229* | 0.0000 | | |

Note: * Statistically Significant at 1% Level; ** Statistically Significant at 5% Level

The next step is the determination of correlations between the dependent variable (GDP per capita) and the rest of the explanatory variables included in our econometric analysis. According to the results presented in Table 4 , high positive correlations are observed between GDP per capita and Brent Crude Oil Prices

(0.31), Exports and GDP per capita (0.58), respectively between Imports and our dependent variable (0.35).

**Table 4. The correlation of variables**

| Variable | GDP per capita | Brent Crude Oil Prices | CO2 emissions | Exports | Imports | GOV Expenditure | FDI |
|---|---|---|---|---|---|---|---|
| **GDP per capita** | **1.00** | 0.3060 | -0.0078 | 0.5834 | 0.3505 | 0.3362 | 0.1401 |
| **Brent Crude Oil Prices** | 0.3060 | **1.00** | 0.3180 | 0.7572 | 0.3540 | 0.2273 | -0.053 |
| **C02 Emissions** | -0.007 | 0.3182 | **1.00** | 0.2549 | 0.1133 | 0.0074 | 0.0647 |
| **Exports** | 0.5834 | 0.7572 | 0.2549 | **1.00** | 0.5806 | 0.3408 | 0.0997 |
| **Imports** | 0.3505 | 0.3540 | 0.1133 | 0.5806 | **1.00** | 0.4521 | 0.2245 |
| **GOV Expenditure** | 0.3362 | 0.2273 | 0.0074 | 0.3408 | 0.4521 | **1.00** | 0.1900 |
| **FDI** | 0.1401 | -0.053 | 0.0647 | 0.0997 | 0.2245 | 0.1900 | **1.00** |

Furthermore, the econometric analysis is based on the estimation of a data panel methodology using the EViews12 software program.

According to the Baltagi (2008), Codirlașu and Moinescu (2010), panel data is a dataset in which the behaviours of entities are observed across time. The main purpose of panel analysis consists in controlling for variables that cannot be observed or measured across entities; or variables that change over time but not across entities (Bell and Jones, 2015; Schmidheiny, 2013).

In our case, for each of two econometric models, we used 3 types of panel-type specifications, such as: Common Effects Model or POLS Model, Fixed Effects Model (FE) regression model and Random Effects Model (RE) in order to estimate the economic growth in the six Caspian countries. The general form of the 2 econometric models proposed to estimate the level of economic development in the Caspian region are presented below.

$$GDP\ per\ capita_{\ it} = \beta_0 + \beta_1 \times Brent\ Crude\ Oil\ Price_{it} + \beta_2 \times CO2\ Emissions_{it} + \beta_3 \times FDI_{it} + \beta_4 \times Exports_{it} + \alpha_i + \varepsilon_{it} \textbf{ (Model 1)}$$

$$GDP\ per\ capita_{\ it} = \beta_0 + \beta_1 \times Imports_{it} + \beta_2 \times GOV\ Expenditure_{it} + \beta_3 \times FDI_{it} + \beta_4 \times Brent\ Crude\ Oil\ Prices_{it} + \alpha_i + \varepsilon_{it} \textbf{ (Model 2):}$$

Where $\beta_0$ is the intercept term (constant term), $\beta_{1,}, \beta_2; \beta_3;\ \beta_4$ are the coefficients for each independent variable; $\alpha_i$ is the country-specific error component and this varies between countries, and $\varepsilon_{it}$ represents the error term which captures the impact of unobserved variables that vary both across countries and over a period of time (time horizon); $i$ represent the country ($i = 1\ to\ 6$) and $t$ indicates the time ($t = 1997\ to\ 2018$) for each model.

The last part of the econometric analysis consisted in testing the regression methods applied and choosing the most appropriate regression for each econometric model. Specifically, we used the Chow test, the Huasmann test, and the Lagrange Multiplier (LM) test to see which of the 3 types of panel specifications is better in estimating the economic growth models in these six Caspian countries ( Drukker, 2003; Hoechle, 2007).

The econometric analysis was followed by testing the homoscedasticity hypothesis for each model by using the Breusch-Pagan Test. Also, we tested the existence of cointegration relation between dependent and specified independent variables of the 2 models by applying Kao Residual Cointegration Test and Pedroni Test (Kao, 1999; Pedroni, 2004). But, in order to validate the results of cointegration tests, we performed a VECM analysis by validating or not the long-term relationship between GDP per capita and the explanatory variables. In this regard, we investigated the significance of the Error Correction Term-ECT.

## 3. Results

In this section are presented and interpreted the main results obtained by applying the panel of the econometric analysis in order to measure the degree of economic growth (in terms of GDP per capita) in the six Caspian countries in the specified period 1997-2018. In the 3.1 part we will present and interpret the main estimated coefficients based on the two econometric models used; in the next part (3.2) we will investigate and evaluate the robustness for each econometric model, and finally (3.3), we will examine and compare which is the most appropriate panel regression specification.

### 3.1. Results obtained from the estimation of the panel regression coefficient

The econometric results of Model 1 (Table 5) show that for each panel specification (Common Effect Model, Fixed Effect Model, and Random Effect Model) the coefficients are statistically significant with at least 5% level of confidence.

**Table 5. The results of coefficients for Model 1**

| Panel Specifications | $\beta_0$ | Brent Crude Oil Price | CO2 Emissions | FDI | Exports |
|---|---|---|---|---|---|
| Common Effects | 0.033434* | -0.049438* | -0.10743*** | 0.004129 | 0.174101* |
| Fixed Effects | 0.033741* | -0.04316** | -0.09617*** | 0.005629 | 0.163691* |
| Random Effects | 0.033681* | -0.04442** | -0.09869*** | 0.005326 | 0.165810* |

Note: * denotes/indicates statistical significance at 1% level; ** indicate statistical significance at 5% level ; *** indicate statistical significance at 10%

From this point of view, it is observed that in the 3 panels, the level of GDP per capita is negatively influenced by the global oil price (in our case, the Brent Crude Oil Price) as well as the quantity of carbon dioxide (CO2 Emissions).Also, the volume of exports has a direct and positive impact on economic growth in the analysed Caspian countries. Moreover, it is notable to see that the volume of foreign direct investments does not have an influence on GDP per capita, and for this reason is highlighted the need to attract these investments opportunities in order to increase the economic and financial potential in extraction and exploration of Caspian energy resources in the near future.

According to these results it is observed a highly significant and positive effect of exports on the level of economic growth in the analysed countries. While the volume of exports increase by 10%, GDP per capita will increase by 1.74% in the case of the regression non-restrictive model, by 1.64% according to the fixed-effects model, respectively, an increase of 1.66% in the case of random effects model.

Regarding the evolution of Brent Crude Oil Price, we observed that it has a relatively low impact on GDP per capita, showing that a 10% increase in the level of oil prices can reduce the degree of GDP per capita by 0.46%. This aspect was presented in other empirical studies (Bolganbayev et al, 2021; Ibrayeva et al, 2018; Stjepanović, 2018), the results confirming the economic potential/growth in the Caspian countries is influenced by the co-movements of oil price that are more and more present nowadays, especially generating a high level of volatility.

Last but not least, the inverse relationship between GDP per capita and C02 Emissions has been suggested, econometric results indicating that a 10% increase in the amount of CO2 emissions causes a decrease in GDP per capita by approximately 1%. For this reasonable aspect, the mitigation and reduction of greenhouse effects remains an important research objective in current empirical and theoretical studies (Horobet et al, 2021; Uçan, 2018; Tugcu, 1018).

On the other hand, the results from the econometric analysis specific to model 2 (Table 6) shows how GDP per capita in the Caspian countries is positively influenced by the amount of imports , the level of the global oil price (Brent Crude Oil Price) and the level of government expenditure. According to each regression method applied, our results suggested that imports, foreign direct investments (FDI) and the global oil price have a direct and positive impact on the measurement of economic growth.

**Table 6. The results of coefficients for Model 2**

| Panel Specifications | $\beta_0$ | Imports | GOV Expenditure | FDI | Brent Crude Oil Price |
|---|---|---|---|---|---|
| Common Effects | 0.034949* | 0.042937*** | 0.052365** | 0.005714 | 0.038502** |
| Fixed Effects | 0.035665* | 0.044389** | 0.037965*** | 0.008107 | 0.040762* |
| Random Effects | 0.035130* | 0.043285** | 0.048731** | 0.006321 | 0.039078* |

Note: * denotes/indicates statistical significance at 1% level; ** indicate statistical significance at 5% level ; *** indicate statistical significance at 10%

Very similar to the econometric results of model 1, we find that there is not a causal relationship between GDP per capita and the FDI, so the estimated coefficients are not statistically significant (i.e.at 1%, 5%, respectively 10% level of confidence). It is measurable while imports are increasing by 10%, GDP per capita reacts in the same way, but still showing a low impact, respectively the GDP per capita increases only by 0.43%.

The same situation is suggested by the evolution of Government Expenditure. While this explanatory variable increases by 10%, GDP per capita tends to increase by 0.52% according to the non-restrictive regression model (Common Effects Model or POLS Model) , respectively by 0.37%, and 0.48% in the case of the restrictive models: Fixed Effects Model (FE) Model and Random Effects Model (RE). This can be explained by the fact that more and more efficient development opportunities are created in key sectors that generate economic growth and a sustainable economic environment in these Caspian countries. Also, GDP per capita in the six Caspian countries continues to increase (0.39%) under the impact of Brent Crude Oil Prices in the analysed time period 1997-2018.

### 3.2. Results of robustness tests in the applied econometric models

In this section, we will illustrate the results regarding the application of the robustness tests for the two econometric models that measure the level of GDP per capita in the case of countries from the Caspian region. The results of the first model are illustrated in the Table 7 below.

**Table 7. Robustness results for Model 1**

| Panel Specifications | R-Squared | Adjusted R-Squared | S.E. of regression | F-statistic | Prob (F-statistic) |
|---|---|---|---|---|---|
| Common Effects | 0.401461 | 0.382609 | 0.042136 | **21.29583** | 0.00000 |
| Fixed Effects | 0.467590 | **0.428314** | 0.040547 | 11.90520 | 0.00000 |
| Random Effects | 0.401441 | 0.382589 | **0.040216** | 21.29409 | 0.00000 |

It is observed that the Fixed Effects panel is the best regression method compared to the other panels used, because the value of the adjusted coefficient of determination (Adjusted R-Squared) is the highest for this type of panel. This value of the Adjusted R-Squared explains that the dependent variable (in our case, GDP per capita) is influenced and determined by 43% of the rest of the independent and explanatory variables included in the first econometric model.

Furthermore, it can also be observed that the Common Effects and Random Effects panels show extremely close values of Adjusted R-Squared, which indicates that GDP per capita is explained by approximately 40% of the included explanatory variables in the model, respectively Brent Crude Oil Prices, Exports, FDI, and CO2 Emissions. In terms of the F-test values, as well as the associated probability values (p-value), we can strongly confirm that the three panel regression methods are statistically validated, with a highly significant 1% confidence level. Also, the best panel specification for estimating GDP per capita in the Caspian countries is the Common Effect Model or POLS Model, with the highest F-test value (F- Statistic = 21.2960).

If taking into consideration the mean square deviation of the errors (SE of regression), our results indicate that the most suitable panel is the Random Effect Model, with the lowest value of this robustness indicator (SE of regression = 0.04022). On the other hand, we analysed the robustness results in the case of the second econometric model that measure the degree of economic growth in Caspian countries which are presented in the Table 8 below.

**Table 8. Robustness results for Model 2**

| Panel Specifications | R-Squared | Adjusted R-Squared | S.E. of regression | F-statistic | Prob (F-statistic) |
|---|---|---|---|---|---|
| Common Effects | 0.199830 | 0.174628 | 0.048719 | 7.929062 | 0.000010 |
| Fixed Effects | 0.295819 | **0.243871** | **0.046631** | 5.694537 | 0.00000 |
| Random Effects | 0.201370 | 0.176216 | 0.047970 | **8.005579** | 0.000009 |

In a similar approach to the first model, the Fixed Effects Model was found to be the appropriate panel specification, accounting for the high value of the adjusted coefficient of determination (Adjusted R-Squared). In this case, GDP per capita is explained in a proportion of 25% by the variation of the explanatory variables included in the model: Brent Crude Oil Prices, FDI, Government Expenditure, and Imports. At the same time, it is observed that these variables included in model 2 have lower impact on the measurement level of GDP per capita, being other imported variables not captured in this model that has an influence on the performance of the GDP per capita in these Caspian countries (Bolganhayev et al, 2021; Tugcu, 2018; Topolewski, 2021). Another similarity in terms of the robustness tests of the 2 models is represented by the statistical significance of these applied panel specifications, which is demonstrated by the extremely close to 0 probabilities associated with the F-test.

Moreover, the Random Effects Panel becomes the most appropriate regression method for estimating the economic growth in these countries surrounding the Caspian Sea. Another aspect which results from the model 2 is represented by the Fixed Effects Panel is also the most appropriate according to the lowest value of the Standard Error of regression (SE of regression =0.046631)

Comparing the 2 econometric models according to robustness indicators, we can strongly affirm that the Fixed Effect Panel is the recommended model for estimating GDP per capita in both cases. Instead, if we focus on the signs of the estimated coefficients, we can conclude for model 1 there is a direct and positive interdependence relation between GDP per capita and exports, while government expenditure has a direct influence on the measurement level of GDP per capita according to the model 2. These results are supported by the studies of Bolganbayev et.al (2021) and Rajbhandari and Zhang (2017) according to which a positive and significant relationship was found between the global oil price and economic growth in the long term by increasing and diversifying the important Caspian oil and natural gas reserves.

### 3.3. Assessment and investigation of the panel specifications in the estimation of GDP per capita

In this section, we will highlight which of the three regression panel methods used is appropriate in estimation the economic performance in the Caspian region. In this regard, several diagnostic tests were used for each individual panel. The results of these tests are illustrated in the table 9 down below

**Table 9. The result of the best panel specifications**

| | The Chow Test | The Hausman Test | The Lagrange Multiplier Test |
|---|---|---|---|
| **Model 1** | 15.454341<br>(0.0086) | 0.938674<br>(0.9189) | 6.040306<br>(0.0140) |
| **Model 2** | 16.868078<br>(0.0048) | 10.396575<br>(0.0343) | 7.652352<br>(0.0057) |

The first test applied was the Chow Test. In a comparative manner, this test evaluates the Common Effects Panel and Fixed Effects Panel and presents the following hypotheses; *H0: There are no individual fixed effects, and H1: There are individual fixed effects*. Therefore, following the Chow test results, it can be stated that in the case of the 2 econometric models it is also suitable using the Fixed Effect Panel in estimating GDP per capita, as demonstrated by associated p-values that represent less than the 5% significance level.

To choose between Fixed Effects Panel and Random Effecst Panel, the Hausman test was applied. The Hausman test indicates the following hypotheses; *H0: There is no correlation between the estimators, and H1: There are random effects*.

For model 1, it was observed that the Random Effects Model is appropriate in estimating GDP per capita, therefore validating the null hypothesis (p-value>0.05). This is also not valid for model 2; in this case the Fixed Effects Panel being more fitting and the alternative hypothesis was accepted (p-value<0.05).

Last but not least, by applying the Lagrange Multiplier test (LM test), we can evaluate in a comparative manner the Random Effects Panel and Common Effects Panel. The LM test has the following hypotheses; *H0: There are no random effects, and H1: There are random effects*. The results suggested that the Random Effects Panel is adequate in estimating GDP per capita in both situations, accepting the alternative hypothesis (p-value<0.05).

Consequently, following these diagnostic tests it is confirmed that the more suitable panel regression method is provided by Fixed Effect Panel and Random Effect Panel in estimation GDP per capita in the case of the Caspian countries.

**Table 10. Residual Cross-Section Dependence Test (Breusch-Pagan Test)**

| | Fixed Effects Panel | Random Effects Panel |
|---|---|---|
| **Model 1** | 21.01235 (*0.1364*) | 20.94088 (*0.1387*) |
| **Model 2** | 18.16823 (*0.2539*) | 17.79325 (*0.2737*) |

Note: in the brackets is the p-value associated with these residual tests.

Another aspect of the panel analysis was the application of econometric tests that verify the homoscedasticity hypothesis in the error series. Thus, according to the results of the Breusch-Pagan test (Table 10), it is observed that both applied models meet the homoscedasticity hypothesis, since this p-value is not less than 0.05. To test the existence of cointegration relationship between the dependent variable (GDP per capita) and explanatory variables (Brent Crude Oil Prices, Exports, Imports, Government Expenditure, CO2 Emissions, and FDI), we applied the several cointegration tests, i.e. Kao Residual Cointegration Test and Pedroni Test. The results are shown in the table 11 and table 12.

**Table 11. The results of Kao Residual Cointegration Test**

| **ADF Test** | **T statistic** | **Prob.** | **Residual Variance** | **HAC variance** |
|---|---|---|---|---|
| **Model 1** | -4.522613 | 0.0000 | 0.059473 | 0.008561 |
| **Model 2** | -3.816720 | 0.0001 | 0.002124 | 0.000728 |

**Table 12. The results of Pedroni Test**

| **Model 1** | | | **Model 2** | |
|---|---|---|---|---|
| Method | Statistic | Prob. | Statistic | Prob. |
| Panel v-statistic | -3.119499 | 0.9991 | -2.510449 | 0.9940 |
| Panel rho-statistic | 1.212456 | 0.8873 | 1.730980 | 0.9583 |
| Panel PP-statistic | -8.302176 | 0.0000 | -1.687829 | 0.0457 |
| Panel ADF-statistic | -5.690017 | 0.0000 | -1.749600 | 0.0401 |
| Group rho-statistic | 2.121789 | 0.9831 | 2.276006 | 0.9886 |
| Group PP-statistic | -9.875377 | 0.0000 | -3.496132 | 0.0002 |
| Group ADF-statistic | -5.332305 | 0.0000 | -2.376461 | 0.0087 |

The obtained results confirmed that there is a possible long-run relationship between the variables included in these two models (Ibrayeva et al, 2018; Kasperowicz, 2014; Lim et al, 2014). To asses and investigate if there is a certain long-run relationship between GDP per capita and explanatory variables, we performed the VECM's error correction term (C1-ECT) analysis.

**Table 13. The result of ECT term**

| Error Correction Term C(1) | Coefficient | Std.error | t-Stat. | Prob. | Long-run determination |
|---|---|---|---|---|---|
| **Model 1** | 0.001162 | 0.002556 | 0.454537 | 0.6504 | No |
| **Model 2** | 0.002150 | 0.001918 | 1.120719 | 0.2650 | No |

These results (Table 13) indicate that there is no long-term relationship between GDP per capita and the explanatory variables for each model, according to the term C(1) which is not statistically significant at the 5% level.

**4. Conclusion**

The main objective of our study was to estimate the level of GDP per capita in the six Caspian countries in the period 1997 to 2018. In this sense, two econometric models were performed, both of them based on the panel specification analysis. According to this methodological approach, there was possible to show how the economic growth (GDP per capita) in the Caspian countries is influenced by the following explanatory variables: Brent Crude oil prices, Exports, Imports, Government Expenditure, Foreign Direct investments, and CO2 Emissions.

Our results showed that GDP per capita is influenced in a direct and positive manner by the volume of exports and imports. This is not a surprisingly aspect, because these Caspian countries represent the main strategic points for the supply of energy resources, especially oil and natural gas.

Moreover, it was noted how the global oil price (in our case, Brent Crude Oil Price) continue to have an important and accentuated positive impact on economic growth for each Caspian country. However, it is interesting to see whether this causal relationship will be able to be maintained in the long term, taking into account the current unpredictable events that can generate the tendency of volatility in the global economic and financial context.

Tested by VECM model and Pedroni and Kao cointegration tests, it was found that the relationship between GDP per capita and the rest of the variables is not maintained in the extended period of time. Thus, in future research we propose to analyse this long-term impact of Brent Crude Oil Price for many producing and exporting counties in the field of energy resources by adopting and applying a modified panel analysis (FMOLS or DOLS). Therefore, the inverse and indirect relationship between GDP and CO2 Emissions was observed.

We conclude the active and solid support FOR a sustainable economic growth (encouraging the development of renewable energy sources, such as sunlight, geothermal heat, and biomass) within the Caspian countries must be an important priority in the future. Interestingly, both of these models demonstrated there is not a causality relation between the GDP per capita and Foreign Direct Investments which suggested the lack of different investment opportunities in this region based on an existing problematic political system, the increased influence of Russia in this region and the increased instability of the economic and financial environment. Although the Caspian countries are an attractive alternative for their endowment with rich energy resources, for these justified reasons, a possible explanation should be that many investors become less confident and optimistic in starting a new medium and long-term investments in the field of transportation, secure routes and effective supply-chain.

Undoubtedly, our study presents some research limitations. A first limitation derives from the availability of data in order to constitute a balanced and dumpy panel. In our case, it was more difficult to find data in the case of Uzbekistan and Turkmenistan. Another possible limitation derives from the rigorous specifications of the panel analysis/methodology. In further studies we will opt for more advanced econometric methods, as well as including several oil-producing countries (increasing the cross-sectional and temporal dimensions). At the same time, a limit is also suggested from the use of GDP per capita as a principal indicator or proxy that indicates and measures the degree of economic growth. For that reason, to solve this inconvenience we propose to include other explanatory variables, such as: the GINI indicator, the level of labour productivity, inflation rate, and the unemployment rate to investigate and evaluate the causality and interdependence nexus on the economic growth in the Caspian countries.

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