Energy-growth-globalization (EGG) nexus in N-11 countries

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ABSTRACT

This study investigates the correlations of economic growth, energy consumption, and globalization in selected countries. For this purpose, the study gathers data between 1984 and 2013 from 11 countries, where a panel causality test was employed using Konya's (2006) approach based on the Seemingly Unrelated Regressions (SUR) system. Subsequently, the Wald test is conducted with a critical bootstrap value per country, in which the calculations obtained significant statistical figures per country. The results of the two-way causality test between economic growth and energy consumption were found in Egypt, Indonesia, Iran, South Korea, Nigeria, and Turkey. The results of the two-way causality test between globalization and economic growth are known in Bangladesh, Egypt, Indonesia, Iran, South Korea, Mexico, Nigeria, Philippines. Meanwhile, two-way causality between energy consumption and globalization exists in Bangladesh, Egypt, Indonesia, Iran, South Korea, Nigeria, Pakistan, Philippines, and Turkey. Based on these findings, strengthening cooperation is needed so that economic growth, energy consumption, and globalization continue to grow.

1. Introduction

Economic growth is an essential part of macroeconomics. Each country continues to try to find ways to promote higher economic growth yearly. In the case of developing countries, they try their best to become strong economies like developed countries. This effort is carried out, and it is hoped that an effect will increase welfare for the country (Ikhsan et al., 2022). According to classical theory, economic growth is determined by capital and labor. When both inputs increase, economic growth also increases. The development of the latest theory by neo-classical incorporates elements of population and technology (Romer, 2012). Another factor that is considered an input for economic growth is energy (Destek and Aslan, 2017). The discussion about energy is an exciting thing among researchers. Each country is competing to explore the natural resources they have. Up to now, at least two energies have been identified: renewable energy (water, wind, geothermal, and biomass) and non-renewable energy (crude oil, gas, and coal). One of the reasons for the drive to diversify energy is the high demand for goods. Producers catch the signal as an opportunity to produce more goods by expanding new industries. Therefore, energy and economic growth are interconnected (Saïdi et al., 2017). Many previous researchers continue to confirm these two elements and some of them find consensus results (Mirza and Kanwal, 2017; Saïdi et al., 2017; Khan et al., 2021; Rahman, 2021), there is only one direction (Appiah, 2018; Pinzón, 2018), and it is not proven to exist (Chontanawat, 2020).

In today’s modern era, demand for goods can occur for domestic and international needs. A country generally tries to produce its goods without interference from other countries. However, the existence of resources is a problem because every country has abundant natural resources but is limited in human resources, or vice versa. Therefore, opening the door to other countries through cooperation provides economic benefits, a concept known as globalization. This concept was introduced in the early 2000s. Globalization describes a shift in the economy, becoming integrated into a more comprehensive economy and society (Hill and Hult, 2019). Shahbaz et al. (2021) explain that globalization has an important role and is believed to be an object in encouraging energy consumption and stimulating economic growth.

Regarding globalization, economic observers group countries based on specific criteria to compete with developed countries. One is N-11 Country, Next Eleven, which Goldman Sach identified. These countries have lower-middle-income statuses, such as Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea, and Vietnam. These 11 countries are predicted to have the same economic opportunities as group countries such as Brazil, Russia, India,
China, and South Africa (BRICS). In addition, the country is also estimated to have a financial advantage because of its stable macroeconomic and political potential (Chang and Fang, 2022).

The World Development Indicator (WDI) data by the World Bank released data on the economic growth of these 11 countries, which each year continues to experience a significant increase. Figure 1 shows that in 1984 the economic growth per capita was 1.8 trillion dollars, and 6.1 trillion in 2013. In 30 years, the increase in per capita economic growth reached 227 percent, with an average economic growth rate of 4.9 per year. Of course, developing countries are not the same as developed countries. The use of this country's energy is still massive with fossil energy. Figure 2 shows that energy consumption has increased from 29 million tons of oil in 1994 to its peak in 2005 of 58 million tons of oil. However, there was a decrease until 2013 to 27 million tons of oil. This decline was due to unstable oil prices and the shift from fossil to renewable energy. At the same time, the globalization index of 11 countries experienced a reasonably high jump from 37.72 points in 1983 to 62.20 points in 2013 (an increase of 64 percent) with an average of 1.74 percent per year (Figure 3). The higher globalization shows, the more significant the role of cooperation between countries towards other countries. Indirectly, every country began to take advantage of globalization as the main gate to encourage the economy. Based on the development of the three data, there are exciting things where the patterns of movement of economic growth, energy consumption, and globalization tend to be the same. When economic growth increases, energy consumption, and globalization also increase.

Most of the literature is very consistent in finding that economic growth and energy consumption are correlated, so it is natural for this pattern to form. However, the assumptions used are only two variables. The era of globalization provides opportunities for every country to open trade gates to other countries in the form of cooperation. The goal is to get access to resources (i.e., oil, technology, capital) from a country intended to increase economic growth. Based on this situation, the problem of this research is whether economic growth, energy consumption, and globalization have a causal relationship?

This research can be considered a development of previous literature in the field of energy economics. However, in this study, some things are different from the existing literature, among others. First, to our knowledge, most of the research literature presents the relationship between economic growth and energy consumption in particular countries but has little application in panel data, especially N-11. Anticipate that our study will significantly contribute to the literature in filling this gap. Second, the combination of variable relationships that we use, including elements of globalization, is scarce, especially the relationship between globalization and energy consumption and globalization on economic growth. So this finding is the first introduction to the energy-growth-globalization (EGG) nexus. Third, this study uses Konya’s (2006) bootstrap panel Granger causality method in the trivariate system of equations. Fourth, unlike the previous method, it only answers one answer so that its implementation applies to all so that the presentation of results is more specific for each country. Fifth, we employed the Cross-sectional Dependence (CSD) method to determine the presence or absence of linkages between countries. Additionally, we used Pesaran and Yamagata's (2008) study to test for heterogeneity between the countries.

The last part of this introduction is the structure of the writing, with Section 2 describes literature of variables. Meanwhile, Section 3 discusses the data and strategies used, and Section 4 describes the test results, ending with the analysis results and policy implications in Section 5.

2. Literature review

2.1. Linkage between energy consumption and economic growth

Studies on the relationship between energy consumption and economic growth have had their charm in recent years. According to the literature of Ozturk (2010), four hypotheses test the relationship between the two variables. The first is the growth hypothesis, in which energy consumption presents a one-way relationship with economic growth. An indication of this hypothesis explains that an increase in energy consumption will increase economic growth. Second is the conservative hypothesis that economic growth is related to energy consumption. This idea explains that increasing energy consumption is highly dependent on economic growth. The last element is the feedback hypothesis, which describes the effect of energy consumption on economic growth. The final hypothesis is neutral, indicating no relationship between the two factors. The four hypotheses are strengthened by previous studies (Table 1), where various methods and different samples obtained the results of these hypotheses. Apergis and Tang (2013), Destek and Aslan (2017), Ozcan and Ari (2015) and Appiah (2017) found the growth hypothesis findings. Ozcan and Ari (2015), Destek and Aslan (2017), Pinzón (2018) and Munir et al. (2020) found the conservative hypothesis findings. While the feedback findings were found in the study of Apergis and Payne (2010), Destek and Aslan (2017), Gorus and Aydin (2019), Khan et al. (2021), Rahman (2021), and Ikhsan et al. (2022). Meanwhile, the neutral hypothesis was found by Sari and Soytas (2009), Ozturk and Acaravci (2011).

2.2. Linkage between globalization and economic growth

Globalization has a critical role in economic growth besides energy consumption, albeit the literature on these studies is limited (Table 2). Globalization provides more space for countries to open cooperation with other countries. Of course, globalization is not the same as open trade which is limited to the definition of commodity value only. More than that, the role of globalization is very important in the economy such as cooperation in improving technology, capital, or human resources so that countries bind each other in the long term. If this limits globalization, the country will only rely on local resources and the economy will stagnate. Kilic (2015), using the Dumitrescu-Hurlin method in developing countries, reveals two-way results vis-à-vis globalization and economic growth. Meanwhile, Olimpi & Stela (2017) found a one-way relationship with the paired Granger method in Romania. This finding is in line with the study of Yang et al. (2021), focusing on the countries with the most

![Figure 1. Real GDP development in N-11 countries 1984–2013. Source: World development indicator (WDI).](image-url)
significant health expenditures. Etokakpan et al. (2020) also found a neutral relationship in Malaysia.

2.3. Linkage between globalization and energy consumption

Globalization and energy consumption have contributed to developing energy usage increasing domestic oil imports and exports to foreign countries. Consequently, countries are less concerned about their natural resource limitations or the status of net oil-importing countries. For countries producing net oil exports, globalization is an advantage for trade. Therefore, in terms of energy consumption, the two statuses of these countries are mutually beneficial. Just like the literature on globalization and economic growth, this literature is also still rare. In Table 3, the first study of this study was conducted by Shahbaz et al. (2018) using the Dumitrescu-Hurlin method and found a two-way relationship in 25 developed countries, and this finding is reinforced by Fahimi et al. (2021). Most of the findings on globalization have a one-way effect on energy consumption (Etokakpan et al., 2020; Usman et al., 2021; and Shahbaz et al., 2021). The relationship between the direction of energy consumption and globalization was found by Shahbaz et al. (2021) through the Time-varying Granger method.

3. Data and methodology

One of the significant challenges this study faces is the minimal data accessibility. Hence, this study utilized the annual data of 11 countries between 1984 and 2013 with 330 observations. In this study, the variables are measured as follows: economic growth (GDP) using a constant 2010 GDP in dollars and Energy Consumption (EC) in kg of oil equivalent. Meanwhile, Globalization (GLO) is measured by using a constant 2010 GDP in dollars and Energy Consumption (EC) in study, the variables are measured as follows: economic growth (GDP) data accessibility. Hence, this study utilized the annual data of 11 countries.

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Figure 2. Development of energy consumption in N-11 1984–2013. Source: World development indicator (WDI).

Figure 3. Development of globalization in next eleven countries 1984–2013. Source: KOF swiss economic institute.

variables x and y (if using two) are stationary and cointegrated. In addition, the VAR model has one answer for all samples. However, problems arise when using panel data in heterogeneous conditions. As a result, the resulting analysis does not provide a unique solution. Konya (2006) introduced the bootstrap panel causality method with the Seemingly Unrelated Regression (SUR) estimator to solve this problem. This method has several advantages; among others, first, it is very robust against stationarity and cointegration, so these two conditions do not need to be tested again for panel data (Destek and Aslan, 2017). Second, each country’s statistical results are based on bootstrapping (Zhang et al., 2016). Third, causality equations can be formed as bivariate and trivariate SUR. Fourth, SUR is more efficient in estimating country by country than Pooled Least Square (PLS) (Zhang et al., 2016). We construct the equations of this system with the trivariate SUR (Tekin, 2012) with the following equation:

\[
y_{1t} = \alpha_{11} + \sum_{l=1}^{l_n} \beta_{1l}y_{1,t-l} + \sum_{l=1}^{l_n} \delta_{1l}x_{1,t-l} + \epsilon_{11t}
\]

\[
y_{2t} = \alpha_{21} + \sum_{l=1}^{l_n} \beta_{2l}y_{2,t-l} + \sum_{l=1}^{l_n} \delta_{2l}x_{2,t-l} + \epsilon_{21t}
\]

\[
\vdots
\]

\[
y_{Nt} = \alpha_{N1} + \sum_{l=1}^{l_n} \beta_{1l}y_{N,t-l} + \sum_{l=1}^{l_n} \delta_{1l}x_{N,t-l} + \epsilon_{1Nt}
\]

\[
\vdots
\]

\[
x_{1t} = \alpha_{21} + \sum_{l=1}^{l_n} \beta_{2l}y_{1,t-l} + \sum_{l=1}^{l_n} \delta_{2l}x_{1,t-l} + \epsilon_{21t}
\]

\[
x_{2t} = \alpha_{21} + \sum_{l=1}^{l_n} \beta_{2l}y_{2,t-l} + \sum_{l=1}^{l_n} \delta_{2l}x_{2,t-l} + \epsilon_{22t}
\]

\[
\vdots
\]

\[
x_{Nt} = \alpha_{21} + \sum_{l=1}^{l_n} \beta_{2l}y_{N,t-l} + \sum_{l=1}^{l_n} \delta_{2l}x_{N,t-l} + \epsilon_{2Nt}
\]

and
to X if all $\delta_1$ are zero, but not all $\beta_1$ are zero; (iii) there is a bidirectional Granger causality relationship between X and Y if $\delta_1$ and $\beta_1$ are not zero; (iv) there is no Granger causality relationship between X and Y if $\delta_1$ and $\beta_1$ are zero. The results of causality testing are very sensitive to lag, so optimal lag testing is necessary. However, lag testing in the case of large panel systems is very computationally taxing. Therefore, we assume a lag between 1 and 4; our best lag measurement uses the Schwartz Criterion (SC) information. The procedure was strongly suggested by Könya (2006) and has been implemented by Zhang et al. (2016). In addition, we limit the use of variables to three to avoid multicollinearity problems in the system. Könya (2006) also explains that the SUR estimator applied in panel Granger causality because there are contemporaneous correlations (correlated between residuals). If no contemporaneous correlation then the OLS estimator is more efficient. Detection can be tested through the latest methods, namely the Cross-Sectional Dependence (CSD) test, and the Slope Homogeneity Test.

The CSD tests is used on panel data that has specific conditions. In particular, the relationship in panel data caused by globalization that the economy between countries affects the economies of other countries (Destek and Aslan, 2017; Ozcan and Ozturk, 2019). Therefore, it is necessary to test the existence of the CSD. There are three forms of tests to observe this idea, namely the Lagrange Multiplier (LM), otherwise known as Cross-sectional Breusch-Pagan (CSBP) (Breusch and Pagan, 1980) and has been implemented by Zhang et al. (2016). Therefore, it is necessary to test the existence of the CSD. There are three forms of tests to observe this idea, namely the Lagrange Multiplier (LM), otherwise known as Cross-sectional Breusch-Pagan (CSBP) (Breusch and Pagan, 1980) and the two cross-sectional tests (Pesaran, 2021). The latter is a derivative of LM in the form of one, and the final test is based on the pairwise correlation.

The CDBP test for CSD is valid when $T \rightarrow \infty$ where $N$ is constant and the assumptions used in the test are in the form of uniform panel data. In other words, this test is feasible for a few N and a sufficient T. The formulation of this test is as follows:

$$
\begin{align*}
\tau_{1,i} &= \alpha_{1,i} + \sum_{l=1}^{L} \beta_{1,l} Y_{1,t-l,i} + \sum_{k=1}^{K} \delta_{1,k} X_{1,t-k,i} + \varepsilon_{3,1,i} \\
\tau_{2,i} &= \alpha_{2,i} + \sum_{l=1}^{L} \beta_{2,l} Y_{2,t-l,i} + \sum_{k=1}^{K} \delta_{2,k} X_{2,t-k,i} + \varepsilon_{3,2,i} \\
\vdots \\
\tau_{N,i} &= \alpha_{N,i} + \sum_{l=1}^{L} \beta_{N,l} Y_{N,t-l,i} + \sum_{k=1}^{K} \delta_{N,k} X_{N,t-k,i} + \varepsilon_{3,N,i}
\end{align*}
$$

(3)

Where $Y$ is GDP, $X$ is EC, and $Z$ is GLO. The three elements are formed as endogenous variables in the configuration of a triivariate, and thus causality testing is conducted between GDP and EC, GLO and GDP, and GLO and EC. Meanwhile, $N$ is the area, $t$ is the time, $i$ is the amount of lag, and $\varepsilon$ is the white noise. We form these three variables in the natural logarithm.

For the Granger causality test in the system, the causality relationship for each tested country will be found as follows: (i) there is a one-way Granger causality relationship from X to Y if not all $\delta_1$ are zero, but all $\beta_1$ is zero; (ii) there is a one-way Granger causality relationship from Y

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**Table 1.** Selected literature energy consumption (EC) and economic growth (GDP).

| Author          | Period   | Country               | Method                | Findings                      |
|-----------------|----------|-----------------------|-----------------------|-------------------------------|
| Sari and Soytas (2009) | 1971–2002 | OPEC Countries        | Granger causality     | EC → GDP                      |
| Apergis and Payne (2010) | 1992–2004 | 11 Commonwealth       | Panel causality       | EC→GDP                        |
| Ozturk and Acaracvi (2011) | 1971–2006 | 11 Mena               | ARDL-ECM               | EC   = GDP                    |
| Apergis and Tang (2013) | 1975–2007 | 85 countries          | Toda-Yamamoto         | EC→GDP                        |
| Ozcan and Ari (2015) | 1980–2012 | 15 OECD               | Bootstrap causality   | EC→GDP (UK, Finland, Mexico    |
| Destek and Aslan (2017) | 1980–2012 | 17 emerging economies | Panel bootstrap       | EC→GDP (Turkey)               |
| Munir et al. (2009) | 1971–2004 | 53 countries          | VECM Granger          | EC→GDP (China, Colombia,       |
| Pinzau (2018)     | 1970–2015 | Ghana                 | Toda-Yamamoto         | EC→GDP                        |
| Gorur and Aydin (2019) | 1975–2014 | MENA                  | Frequency Domains     | EC→GDP (FD)                   |
| Ozcan and Ozturk (2019) | 1990–2016 | Emerging countries    | Bootstrap panel       | EC→GDP (Poland)               |
| Chontanawat (2020) | 1971–2015 | ASEAN                 | VECM Granger          | EC   = GDP                    |
| Munir et al. (2020) | 1980–2016 | ASEAN-5               | Dumitrescu-Hurlin     | EC→GDP                        |
| Khan et al. (2021) | 1972–2017 | South Asian           | Dumitrescu-Hurlin     | EC→GDP                        |
| Rahman (2021)     | 1990–2017 | BRICS & ASIA          | Dumitrescu-Hurlin     | EC→GDP                        |
| Ihsan et al. (2022) | 1971–2014 | Indonesia             | Asymmetric            | EC→GDP (negative direct)      |

Note: $\rightarrow$ unidirectional ( ), $\leftarrow$ unidirectional ( ), $\leftrightarrow$ bidirectional, = neutral.

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**Table 2.** Selected literature globalization (GLO) and economic growth (GDP).

| Author          | Period   | Country               | Method                | Findings                      |
|-----------------|----------|-----------------------|-----------------------|-------------------------------|
| Kilic (2015)    | 1981–2011 | Developing countries  | Dumitrescu-Hurlin     | GLO→GDP                      |
| Olimpia and Stella (2017) | 1990–2013 | Romania              | Paired Granger        | GLO→GDP                      |
| Etkokapan et al. (2020) | 1980–2014 | Malaysia             | Granger causality     | GLO   = GDP                   |
| Yang et al. (2021) | 1995–2018 | High healthcare      | Dumitrescu-Hurlin     | GLO→GDP                      |

Note: $\rightarrow$ unidirectional ( ), $\leftarrow$ unidirectional ( ), $\leftrightarrow$ bidirectional.

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**Table 3.** Selected literature globalization (GLO) and energy consumption (EC).

| Author          | Period   | Country               | Method                | Findings                      |
|-----------------|----------|-----------------------|-----------------------|-------------------------------|
| Shababz et al. (2018) | 1970–2014 | 25 developed economies | Dumitrescu-Hurlin     | GLO→EC                        |
| Etkokapan et al. (2020) | 1980–2014 | Malaysia             | Granger causality     | GLO→EC                        |
| Fahnii et al. (2017) | 1970–2015 | MINT                  | Bootstrap panel Granger | GLO→EC                        |
| Osman et al. (2021) | 1980–2018 | Resource-rich Countries | Dumitrescu-Hurlin     | GLO→EC                        |
| Shababz et al. (2021) | 2017Q1–2017Q4 | Ten top global and ten bottoms global | Time-varying            | GLO→EC (Austria, Singapore, Kazakhstan) |

Note: $\rightarrow$ unidirectional ( ), $\leftarrow$ unidirectional ( ), $\leftrightarrow$ bidirectional.
Calculations based on the average \( \Delta \) presented in the form as follows:

\[
CD_{BP} = T \sum_{t=1}^{N-1} \sum_{j=1}^{N} \Delta y_{tj}^2
\]  

However, the test is not valid when \( N \) and \( T \) exhibit large sizes, so Pesaran (2021) reformulates this test with a scaled version, namely:

\[
CD_{LM} = \left( \frac{1}{N(N - 1)} \sum_{i=1}^{N-1} \sum_{j=1}^{N} (T_i \Delta y_{ij}^2 - 1) \right)
\]

The CDLM test is distributed with \( N(0, 1) \) with the null hypothesis, in which there is no CFD. Furthermore, Pesaran (2021) performs the CFS calculations based on the average \( \bar{\Delta} \) with the equation:

\[
CD = \sqrt{\frac{2T}{N(N - 1)} \sum_{i=1}^{N-1} \sum_{j=1}^{N} \bar{\Delta} y_{ij}^2}
\]

Pesaran and Yamagata (2008) discovered the slope homogeneity test with two types of shapes, which determine the existence of heterogeneous parameters in the panel data (Guzel and Okumus, 2020). Generally, countries have a distinct method of developing their economy with various policies, thus making the test necessary (Ozcan and Ozturk, 2019). This test is applied to the method in Eqs. (1), (2), and (3), presented in the form as follows:

\[
\hat{\Delta} = \sqrt{N} \left( \frac{N^{-1} S - k}{\sqrt{2k}} \right)
\]

Where \( k, S, \) and \( N \) indicate the number of exogenous regressors, Swamy’s (1970) statistics, and the number of cross-sections. The test can be increased for a small sample by assuming that the residuals are normally distributed. In this case, the mean and variance are adjusted as follows:

\[
\hat{\Delta}_{adj} = \sqrt{N} \left( \frac{N^{-1} S - E(\hat{\varepsilon}^2)}{\sqrt{\text{var}(\hat{\varepsilon}^2)}} \right)
\]

where \( E(\hat{\varepsilon}^2) = k \) and \( \text{Var}(\hat{\varepsilon}^2) = \frac{2k}{N \Gamma - k - 1} \).

4. Empirical results

The CDLM test is distributed with \( N(0, 1) \) with the null hypothesis, in which there is no CFD. Furthermore, Pesaran (2021) performs the CFS calculations based on the average \( \bar{\Delta} \) with the equation:  

\[
\Delta = \sqrt{\frac{2T}{N(N - 1)} \sum_{i=1}^{N-1} \sum_{j=1}^{N} \bar{\Delta} y_{ij}^2}
\]

Before analyzing the causal relationship of the three variables, the pre-analysis stage is required. Accordingly, critical tests are conducted: the Cross-Sectional Dependence (CSD) (Eqs. (4), (5), and (6)) and slope homogeneity (Eqs. (7) and (8)). Table 5 shows the results of the CSD test, revealing that all variables reject the null hypothesis where there is no relationship between the regions. This result implies that the change in the region’s economy will impact other regions or countries. The slope homogeneity clarifies that the impact of one country presents a different effect between countries. Table 5 shows that 11 countries reject the null hypothesis at the one percent significance level or heterogeneous slope. In other words, the parameters between countries do not have the same form.

After testing the CSD and slope homogeneity, the next step is the panel second generation unit root using the Cross-sectionally IPS (CIPS), and Cross-sectionally ADF (CADF) approaches (Pesaran, 2007). These two tests are carried out if the CDS condition and slope homogeneity are proven to exist. According to Phillips and Sul (2003), the estimation results become inefficient, especially in panel data, if there are CSD problems and slope homogeneity. Although based on the guidelines of Konya (2006), it is stated that this stationarity test is unnecessary, we include the test as a form of information that the use of this causality model should not be stationary at the level. The results in Table 6 show that economic growth, energy consumption, and globalization are not stationary at the levels of both the CADF and CIPS approaches. Testing at the first difference (\( \Delta \)) level found that all variables were stationary in both CADF and CIPS at 1 percent.

4.1. Causality results of energy consumption (EC) and economic growth (GDP)

After testing the CSD and slope detection, the next step tests the Granger bootstrap panel. This method is based on the SUR estimator and tests each region from the panel data through the Wald test (Konya, 2006). This test is similar to the previous Granger causality test, which examines the influence of the past \( X \) on the \( Y \) variable. However, it is probable for the panel data to find erroneous or misleading results due to its heterogeneous nature (Kar et al., 2011), and thus this bootstrap is appropriate (Menyah et al., 2014).

The first results of the Granger SUR causality test are economic growth and energy consumption. The test results are shown in Table 7. The results of this causality test we found a relationship between energy consumption and economic growth in Egypt, Indonesia, Iran, South Korea, Nigeria, and Turkey, where the Wald test was statistically significant at the 1 percent level. Meanwhile, the opposite test between economic growth and energy consumption shows that all countries are significant at the 1 percent level. Based on these findings, it can be concluded that there is a two-way relationship between Egypt, Indonesia, Iran, South Korea, Nigeria, and Turkey. This study is in line with Mirza and Kanwal (2017), Destek and Aslan (2017), Saidi et al. (2017), Gorus and Aydin (2019), Khan et al. (2021), Rahman (2021), and Ikhsan et al. (2022). Interestingly, the sample we used was found in several ASEAN regions, such as Indonesia, which found different things from research by Chontanawat (2020), where the relationship between energy and

| Obs | Mean | Std. dev | Min. | Max. |
|-----|------|----------|------|------|
| GDP | 330  | 26.086   | 0.973| 23.835| 27.856|
| EC  | 330  | 15.028   | 0.723| 13.314| 16.229|
| GLO | 330  | 3.891    | 0.257| 3.206 | 4.345|

Correlation matrix

| GDP | 1    |
| EC  | 0.818| 1    |
| GLO | 0.657| 0.397| 1   |

Table 4. Descriptive statistics and correlation matrix.

| Testing | GDP | EC | GLO |
|---------|-----|----|-----|
| CDSBP   | 1577.217*** | 1130.008*** | 1528.902*** |
| CDAS   | 145.137*** | 102.498*** | 140.531*** |
| CD     | 39.709*** | 33.092*** | 39.093*** |

Slope Test Statistic Prob
| \( \Delta \) | 21.368*** | 0.000 |
| \( \Delta_{adj} \) | 22.948*** | 0.000 |

Note: *** significant at 1 percent.

Table 5. CSD and slope homogeneity results.
economic growth was not proven to exist. On the other hand, a one-way causality relationship is shown for Bangladesh, Mexico, Pakistan, the Philippines, and Vietnam from economic growth to energy consumption, and this finding is in line with Ozcan and Ari (2015), Destek and Aslan (2017) and Pinzón (2018). This finding indirectly explains that every country in the N-11 will increase energy if its economic growth grows.

### 4.2. Causality results of globalization (GLO) and economic growth (GDP)

A second Non-Granger causality test was conducted between globalization and economic growth. The results of this test are shown in Table 8. The first column is the result of the Wald Statistics test and is followed by the critical bootstrap value. Our findings show that feedback causality between economic growth and globalization occurs in 9 countries, except for Pakistan and Turkey, where the Wald statistic is less than the critical value of 10 percent. Meanwhile, the causal test of economic growth against globalization found that the Wald statistic obtained for each country was more significant than the critical value of 1 percent. This means that all countries have a significant influence. Based on these findings, it can be concluded that a two-way causal relationship occurs in Bangladesh, Egypt, Indonesia, Iran, South Korea, Mexico, Nigeria, and the Philippines. This finding is in line with Kilic (2015). Meanwhile, the hypothesis of a one-way relationship between economic growth and globalization only occurs in Pakistan and Turkey. This finding supports the findings by Olimpia and Stela (2017) and Yang et al. (2021); however, it differs from the study of Etokakpan et al. (2020).

### 4.3. Causality results of globalization (GLO) and energy consumption (EC)

Our third test of the Granger causality relationship is between globalization and economic growth. The results of the tests with Wald statistics and critical bootstrap values are presented in Table 9. We find the Wald statistics on energy consumption against globalization rejecting H0 at a significance level of 1 percent for each country. However, the opposite test of globalization on economic growth is only nine countries that reject H0 while two countries, namely Mexico and Vietnam, show the statistical Wald value obtained is smaller than the 10 percent significance level. From these findings, it can be concluded that a two-way relationship occurs in Bangladesh, Egypt, Indonesia, Iran, South Korea, Nigeria, Pakistan, Philippines, and Turkey. This finding is in line with the study of Fahnimi et al. (2021). For the countries of Mexico and Vietnam, it is concluded that there is only a one-way relationship between globalization to energy consumption. These findings show similarities to Shahbaz et al. (2018) and Shahbaz et al. (2021) because countries with

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### Table 6. CADF and CIPS stationarity tests.

| Variables | CADF | CIPS | Conclusion |
|-----------|------|------|------------|
| GDP       | -2.133*** | -2.473*** | I (1) |
| World     | -1.566*** | -2.790*** | I (1) |
| GLO       | -2.222*** | -2.284*** | I (1) |

Note: *** significant at 1 percent.

### Table 7. The panel causality results in energy consumption (EC) and economic growth (EG).

| Country     | Statistics EC→GDP | Critical Value | Statistics GDP→EC | Critical Value |
|-------------|------------------|----------------|-------------------|---------------|
| Bangladesh  | 0.369            | 0.765          | 0.735             | 0.720         |
| Egypt       | 9.256***         | 0.433          | 0.417             | 0.407         |
| Indonesia   | 1.558***         | 0.037          | 0.034             | 0.033         |
| Iran        | 6.237***         | 0.169          | 0.165             | 0.163         |
| South Korea | 0.980***         | 0.763          | 0.755             | 0.751         |
| Mexico      | 0.001            | 0.412          | 0.401             | 0.395         |
| Nigeria     | 1.695***         | 0.346          | 0.333             | 0.324         |
| Pakistan    | 0.570            | 0.929          | 0.923             | 0.920         |
| Philippines | 0.005            | 0.632          | 0.571             | 0.530         |
| Turkey      | 3.428***         | 0.746          | 0.723             | 0.713         |
| Vietnam     | 1.299            | 1.394          | 1.360             | 1.342         |

Note: *** significant at 1 percent. The critical value is obtained by bootstrap 10,000.

### Table 8. Panel causality results from globalization (GLO) and economic growth (GDP).

| Country     | Statistics GLO→GDP | Critical Value | Statistics GDP→GLO | Critical Value |
|-------------|-------------------|----------------|-------------------|---------------|
| Bangladesh  | 3.912***          | 0.603          | 0.584             | 0.573         |
| Egypt       | 27.194***         | 0.080          | 0.074             | 0.070         |
| Indonesia   | 4.330***          | 0.267          | 0.259             | 0.235         |
| Iran        | 5.001***          | 0.003          | 0.002             | 0.002         |
| South Korea | 2.669***          | 0.469          | 0.463             | 0.460         |
| Mexico      | 4.734***          | 0.524          | 0.514             | 0.508         |
| Nigeria     | 2.645***          | 0.037          | 0.031             | 0.028         |
| Pakistan    | 0.064             | 0.184          | 0.181             | 0.180         |
| Philippines | 0.960***          | 0.073          | 0.049             | 0.038         |
| Turkey      | 0.007             | 0.121          | 0.116             | 0.113         |
| Vietnam     | 2.435***          | 0.188          | 0.175             | 0.169         |

Note: *** significant at 1 percent. The critical value is obtained by bootstrap 10,000.
The results of the slope homogeneity test explain that the two tests get a significant relationship signals that the country needs energy as the initial foundation of economics, namely energy-growth-globalization (EGG). To our knowledge, the study of the combination of the three variables has never been carried out. On this basis, we are motivated to fill the void in the literature, which has been discussing energy consumption and economic growth, especially in panel data. We use the bootstrap causality testing method by Kőnya (2006), which produces more country-specific Wald statistics and tests better with the SUR estimator. The procedure for using this method was carried out using the Cross-sectional Dependence (CSD) approach by Pesaran (2021) and the slope homogeneity by Pesaran and Yamagata (2008), as well as the Cross-sectional ADF (CADF) and Cross-sectional IPS (CIPS) stationarity testing by Pesaran (2007). Our findings in these pre-estimates explain that statistical results in CSD, across three types of tests, are significant at the 1 percent level, meaning that each country in the study has a relationship with the other countries. The results of the slope homogeneity test explain that the two tests get a statistically significant value at the 1 percent level. This result indicates that each country has different parameters, so the country in the sample is heterogeneous. The last test was stationary, showing that all variables, based on the CADF and CIPS approaches, were stationary at the first difference level.

Based on the empirical results, we found that there findings, First, the results of the Granger non-causality test between energy consumption and economic growth found two conclusions: a two-way relationship and a one-way one. Two-way relations occur in Egypt, Indonesia, Iran, South Korea, Nigeria, and Turkey. Meanwhile, the one-way relationship between economic growth to energy consumption applies in Bangladesh, Mexico, Pakistan, the Philippines, and Vietnam. The linkage of globalization and energy consumption reflects how a country obtains sufficient resources to revive its economy. With globalization, oil-importing countries such as Indonesia and oil-exporting like Nigeria have an advantage over the two (Fahimi et al., 2021). However, increasing globalization also creates problems if one country closes access to needed goods (Shahbaz et al., 2018). For example, a decline in oil prices is so unfavorable to oil-exporting countries that they reduce their oil exports. This effect creates problems for oil-importing countries, namely supply shortages, resulting in stalled economic growth.

Based on these findings, important policies need to be observed. The existence of cross-sectional dependence (CSD) in N-11 indicates that if one country has problems with globalization, such as the economic crisis, other countries will also feel the impact. This evidence shows the existence of a significant relationship between energy-growth-globalization (EGG). In particular, the role of globalization in increasing economic growth and encouraging energy consumption. Therefore, N-11 needs to strengthen cooperation. Not only to strengthen economic growth but also to strengthen and share environmentally friendly-based technologies and divert fossil energy resources to renewable energy in order to future economic and sustainability.

5. Conclusion and policy implication

This study examined the causal relationships of energy consumption, economic growth, and globalization in 11 countries between 1984 and 2013. In this context, we introduce a new branch of research in the field of economics, namely energy-growth-globalization (EGG). To our knowledge, the study of the combination of the three variables has never been carried out. On this basis, we are motivated to fill the void in the literature, which has been discussing energy consumption and economic growth, especially in panel data. We use the bootstrap causality testing method by Kőnya (2006), which produces more country-specific Wald statistics and tests better with the SUR estimator. The procedure for using this method was carried out using the Cross-sectional Dependence (CSD) approach by Pesaran (2021) and the slope homogeneity by Pesaran and Yamagata (2008), as well as the Cross-sectional ADF (CADF) and Cross-sectional IPS (CIPS) stationarity testing by Pesaran (2007). Our findings in these pre-estimates explain that statistical results in CSD, across three types of tests, are significant at the 1 percent level, meaning that each country in the study has a relationship with the other countries. The results of the slope homogeneity test explain that the two tests get a statistically significant value at the 1 percent level. This result indicates that each country has different parameters, so the country in the sample is heterogeneous. The last test was stationary, showing that all variables, based on the CADF and CIPS approaches, were stationary at the first difference level.

Based on the empirical results, we found that there findings, First, the results of the Granger non-causality test between energy consumption and economic growth found two conclusions: a two-way relationship and a one-way one. Two-way relations occur in Egypt, Indonesia, Iran, South Korea, Nigeria, and Turkey. Meanwhile, the one-way relationship between economic growth to energy consumption applies in Bangladesh, Mexico, Pakistan, the Philippines, and Vietnam. The linkage of globalization and energy consumption reflects how a country obtains sufficient resources to revive its economy. With globalization, oil-importing countries such as Indonesia and oil-exporting like Nigeria have an advantage over the two (Fahimi et al., 2021). However, increasing globalization also creates problems if one country closes access to needed goods (Shahbaz et al., 2018). For example, a decline in oil prices is so unfavorable to oil-exporting countries that they reduce their oil exports. This effect creates problems for oil-importing countries, namely supply shortages, resulting in stalled economic growth.

Second, the results of the Granger non-causality test between globalization and economic growth found two forms of causality, namely reciprocity and one direction from economic growth to globalization. Two-way relationships were confirmed for Bangladesh, Egypt, Indonesia, Iran, South Korea, Mexico, Nigeria, Philippines. At the same time, the one-way relationship applies in Pakistan and Turkey. These findings explain that efforts to increase economic growth can be made by opening up workplaces with other countries. Indirectly, globalization acts as a space for exchanging technology and knowledge (Fahimi et al., 2021). On the other hand, the state has the opportunity to produce goods massively if the conditions for domestic demand have been met. The steps taken by the state are to export these goods to the destination country. This result is very beneficial for developing countries (Kílíc, 2015).

Third, the non-causality test results between globalization and economic growth found a two-way and a direct relationship. Bangladesh, Egypt, Indonesia, Iran, South Korea, Mexico, Nigeria, Philippines, and Turkey have two-way relations. Meanwhile, the one-way relationship between globalization to energy consumption is only found in Mexico and Vietnam. The linkage of globalization and energy consumption reflects how a country obtains sufficient resources to revive its economy. With globalization, oil-importing countries such as Indonesia and oil-exporting like Nigeria have an advantage over the two (Fahimi et al., 2021). However, increasing globalization also creates problems if one country closes access to needed goods (Shahbaz et al., 2018). For example, a decline in oil prices is so unfavorable to oil-exporting countries that they reduce their oil exports. This effect creates problems for oil-importing countries, namely supply shortages, resulting in stalled economic growth.

Declarations

Author contribution statement

Kamal Fachrurrozi: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
Appendix 1. Procedure to Generate Bootstrap

Konya (2006) revealed the procedure to generate bootstrap samples, and country-specific critical values, which comprise the following steps:

**Step 1:** Estimate Eqs. (1) and (2) under the null hypothesis of no-causality from X to Y by imposing \( \delta_{ij} = 0 \) for all \( i \) and \( j \), subsequently obtaining the residual. These residuals develop the \( N \times T|\epsilon_{0ij}| \) matrix.

**Step 2:** Re-sample the residuals by randomly selecting the entire column from the matrix \( |\epsilon_{0ij}| \) at a time. The selected bootstraps residuals are denoted as \( |\epsilon_{0ij}|^{-1} \), where \( t = 1, 2, 3, T^* \), and \( T^* \) can be greater than \( T \).

**Step 3:** Generate the bootstrap sample \( Y \) under the assumption of no-causality from \( X \) to \( Y \) as \( y_{jt}^* = \tilde{\alpha}_j + \frac{yj}{T1}\sum p_{ij}p_{ij}^{-1} + \epsilon_{0ij}^* \).

**Step 4:** Substitute \( y_{jt}^* \) for \( y_{jt} \), estimate Eq. (2) without any parameter restrictions. Subsequently, the Wald test is conducted for each country to test for the null of no-causality.

**Step 5:** Develop the empirical distributions of the Wald test statistics, repeating steps 2-4 multiple times to generate the critical bootstrap values. This approach is made by selecting the appropriate percentiles of the sampling distributions. We obtained the critical bootstrap values from the 10,000 replications in this step.

**References**

Apergis, N., Tang, C.F., 2013. Is the energy-led growth hypothesis valid? New evidence from a sample of 85 countries. Energy Econ. 38, 24–31.
Apergis, N., Payne, J.E., 2010. The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states. Energy Pol. 38 (1), 650–655.
Appiah, M.O., 2018. Investigating the multivariate Granger causality between energy consumption, economic growth, and CO2 emissions in Ghana. Energy Pol. 112 (October 2017), 198–208.
Brelsau, T.S., Pagan, A.R., 1980. The Lagrange multiplier test and its applications to model specification in econometrics. Rev. Econ. Stud. 47 (1), 239.
Chang, C.-L., Fang, M., 2022. Renewable energy-led growth hypothesis: new insights from BRICS and N-11 economies. Renew. Energy 188, 788–800.
Chontanawat, J., 2020. Relationship between energy consumption, CO2 emission and economic growth in ASEAN: cointegration and causality model. Energy Rep. 6, 660–665. Elsevier Ltd.
Dentek, M.A., Aslan, A., 2017. Renewable and non-renewable energy consumption and economic growth in emerging economies: evidence from bootstrap panel causality. Renew. Energy 111, 757–763.
Dreher, A., 2006. Does globalization affect growth? Evidence from a new index of globalization. Appl. Econ. 38 (10), 1091–1110.
Etokakpan, M.U., Solarin, S.A., Yorucu, V., Bekun, F.V., Sarkodie, S.A., 2020. Modeling natural gas consumption, capital formation, globalization, CO2 emissions and economic growth nexus in Malaysia: fresh evidence from combined cointegration and causality analysis. Energy Strategy Rev. 31, 100526.
Fahimi, A., Olson-Shie-Williams, G., Akadiri, S., 2021. Examining the causal relationship between globalization and energy consumption in MINT countries: evidence from bootstrap panel Granger causality. Int. J. Finance Econ. 26 (2), 1815–1837.
Khan, M.B., Saleem, H., Shabbir, M.S., Huobao, X., 2021. The Effects of Globalization, Energy Consumption and Economic Growth on Carbon Dioxide Emissions in South Asian Countries. Energy and Environment.
Kilic, C., 2015. Effects of globalization on economic growth: panel data analysis for developing countries. In: Petroleum-Gas University of Ploiesti Bulletin, Technical Series, 67, pp. 1–11 (1).
Konya, L., 2006. Exports and growth: Granger causality analysis on OECD countries with a panel data approach. Econom. Modell. 23 (6), 978–992.
Munir, Q., Lean, H.H., Smyth, R., 2020. CO2 emissions, energy consumption and economic growth in the ASEAN-5 countries: a cross-sectional dependency approach. Energy Econ. 85, 104571.
Nasir, M., El Kar, M., Nazlioglu, S., Wolde-Rufael, Y., 2014. Financial development, trade openness and economic growth in African countries: new insights from a panel causality approach. Econom. Modell. 37, 386–394.
Ozcan, B., Arslan, A., 2017. Energy consumption, carbon emissions and economic growth in Pakistan: dynamic causality analysis. Renew. Sustain. Energy Rev. 76, 19–29 (1).
Pesaran, M.H., Yamagata, T., 2008. Testing slope homogeneity in large panels. J. Econom. 140 (1), 198–212.
Pinzón, K., 2018. Dynamics between energy consumption and economic growth in Ecuador: a Granger causality analysis. Econ. Anal. Pol. 57, 88–101.
Polat, E., 2022. The causal nexus between economic growth and energy consumption: new evidence from global panel of 53 countries. Sustain. Cities Soc. 33 (December 2016), 45–56.
Sari, R., Soytas, U., 2009. Are global warming and economic growth compatible? Evidence from five OPEC countries? Appl. Energy 86 (10), 1887–1893.

Shahbaz, M., Balcilar, M., Mahalik, M.K., Akadiri, S. Sain., 2021. Is causality between globalization and energy consumption bidirectional or unidirectional in top and bottom globalized economies? Int. J. Finance Econ. (December 2020), 1–26.

Shahbaz, M., Shahzad, S.J.H., Mahalik, M.K., Sadorsky, P., 2018. How strong is the causal relationship between globalization and energy consumption in developed economies? A country-specific time-series and panel analysis. Appl. Econ. 50 (13), 1479–1494.

Swamy, 1970. Efficient inference in a random coefficient regression model. Econometrica 38 (2), 311–323.

Tekin, R.B., 2012. Economic growth, exports and foreign direct investment in Least Developed Countries: a panel Granger causality analysis. Econ. Model. 29 (3), 868–878.

Usman, M., Balsalobre-Lorenzo, D., Jahanger, A., Ahmad, P., 2021. Pollution concern during globalization mode in financially resource-rich countries: do financial development, natural resources, and renewable energy consumption matter? Renew. Energy 183, 90–102.

Yang, B., Usman, M., Jahanger, A., 2021. Do industrialization, economic growth and globalization processes influence the ecological footprint and healthcare expenditures? Fresh insights based on the STIRPAT model for countries with the highest healthcare expenditures. Sustain. Prod. Consum. 28, 893–910.

Zhang, X., Chang, T., Su, C.-W., Wolde-Rufael, Y., 2016. Revisiting causal nexus between military spending and debt: a panel causality test. Econ. Modell. 52, 939–944.