This is the pre-peer reviewed version of the following article:

Richard Gardiner,Petr Hajek. Interactions among energy consumption, CO2, and economic development in European Union countries. *Sustainable Development* . 01 December 2019.

which has been published in final form at https://doi.org/10.1002/sd.2023.

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This preprint version is available from https://hdl.handle.net/10195/77099.

Interactions among Energy Consumption, CO2 and Economic Development in EU Countries

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Abstract

Sustainable development has become a major problem in EU countries. This has prompted many researchers to examine a broad range of interactions among sustainable development indicators. This study uses the variance decomposition and cointegration approach to assess the causal relationship among energy consumption, CO2 emissions and economic development (GDP, FDI, net exports and employment in industry) in the eight new and fifteen old EU countries. The results confirm the existence of at least long-run equilibrium relationships among economic growth and energy consumption, CO2, FDI and net exports. In addition, short-run bidirectional causality among GDP, energy consumption and CO2 emissions is found for the old EU countries, while unidirectional causalities run from GDP to energy consumption and CO2 emissions in the new EU countries. Evidence from the variance decomposition analysis shows that 22% of the future shock in GDP is due to fluctuations in energy consumption, CO2 and employment in the old EU countries, whereas 53.1% emanates from CO2, employment and FDI in the new EU countries. These findings have potentially important implications for sustainable development and environmental policy in both old and new EU countries.

Keywords: sustainable development, causality, energy, CO2, economy, European union.

1. Introduction

Every nation globally aims to attain higher economic growth through the use of both renewable and non-renewable resources. Although this idea seemed wise and laudable, less concern was given to the impact on environmental quality. Over time, the adverse impact of economic growth on environmental quality began to resurface as emissions of carbon dioxide (CO2) increased coupled with global warming and climate change. This raised concerns among world institutions such as the United Nations Framework Convention on Climate Change, Global Environment Facility, International Union for Conservation of Nature, United Nations Environment Programme and European Environmental Agency as well as many scholars to find the nexus between economic growth, macroeconomic variables and environmental degradation such as CO2 emissions, energy consumption, income, population and foreign direct investment (FDI). Scholars have used different econometric methodologies, time periods and countries/regions to confirm this assertion. Kraft & Kraft (1978) pioneered the topic by determining the causal relationship between energy and gross national product (GNP). The authors found a unidirectional relationship, which implied that the relation runs from GNP to energy consumption, with no relation from energy consumption to GNP. Since then, a number of studies have been conducted to investigate the interactions among energy consumptions, CO2 emissions and economic development (Dogan & Aslan, 2017; Wang et al., 2019). Recent studies have highlighted the contradictory results obtained in earlier empirical studies owing to the outcomes of some macroeconomic variables and economic growth (Amri, 2017; Mardani et al., 2019). Hence, the topic is creating more curiosity for current and further research. Moreover, many regions globally have not been explored to assess the current trend of these variables and their impact on the environment. Here, we aim to bridge those gaps by assessing the current trend of these indicators as well as their policy implications.

The EU is used as a case study because it has shown much concern about economic growth and environmental quality by minimising the adverse effects of CO2 emissions, greenhouse gases (GHG) and energy consumption on economic growth. Explicit evidence can be drawn from the initiative implemented in 1991 to reduce emissions and improve energy efficiency (European Commission, 2019). Similarly, GHG emissions in Europe, according to Micquel Arias Conte (EU climate head), have also declined to their lowest level from 1990–2014, which is about 23% more than the estimated one-fifth projected for 2020. At the same time, the EU economy grew by 46%. This was declared before the Paris Conference in December 2015. The EU has still set a goal to reduce its emissions and minimise global warming by 2 degrees by the middle of this century while ensuring economic growth. Some researchers challenge the possibility of achieving this goal, believing only that the EU can achieve this if its member countries can reduce their recent emissions by three times the current level. Then, it would be possible to achieve the projected abatement target by 2030 (Neslen, 2015).

Here, we assess new and old EU member countries on the grounds that some new members are still in a transitional stage of their economic structure and will continue to affect regional CO2 as a result of their rapid economic growth and development (Azam, 2016). Moreover, old EU member countries (regarded as the West) seemed to have developed their economies earlier than new members. In the same way, the West possesses advanced technology to offset the adverse effect of CO2 and other degradation-related issues. Further, many recent empirical studies have extensively examined both short- and long-run relationships with economic growth-related degradation in the region (Dogan & Aslan, 2017; Stjepanovic, 2018).

The links among economic growth, environmental quality, employment, FDI and net exports are unclear. Earlier works on the economic growth–environmental quality nexus have failed to recognise the effect of employment, FDI and net exports on the economic system. Statistically, a 1% increase in GDP increased employment by 0.21% from 1991 to 2003 (Kapsos, 2006). This signifies that an upsurge in economic growth has a positive effect on employment. An increase in employment also gives rise to consumption and in effect increases pollution in the environment. FDI also assists in the development of human capital, transfer of technology and production of goods and services (McAusland, 2008). By contrast, it tends to contribute 70% of industrial pollution (Melnyk et al., 2014) and other environmental pollution (López-Menéndez et al., 2014). Generally, exports also promote economic growth, especially when specialized in high value-added products such as high-tech manufacturing (Santos et al., 2013). Occasionally, they also induce some countries to specialise in dirty activities (inferior goods or products), which they send abroad without regard for the adverse impact on the environment (McAusland, 2008). Hence, environmental quality is hampered by pollution (air, land and water), compounding the precarious situation of global warming.

Previous empirical studies strongly imply the role of economic development in the nexus between economic growth and environment (Coban & Topcu, 2013; Tiba & Omri, 2017). However, to the best of our knowledge, this is the first study to investigate the causal relationships among energy consumption, CO2 and economic development concurrently between new and old EU countries. This framework makes the current research an interesting topic that aims to bridge that gap in the literature. The contribution of this study to the related literature is two-fold. First, the short- and the long-run effects between economic development and environmental quality have not been tested for new and fifteen old EU countries. Hence, investigating a panel of eight new and fifteen old EU countries might reveal important insights into the effect of different economic environments on the nexus between economic growth and environment. Second, different aspects of economic development, incorporating GDP, FDI, net exports and employment in industry, are considered for the first time in this study. This can shed new light on the complex interactions among economic development, energy consumption and CO2 in the investigated regions.

Taking into consideration recent panel data, we use a panel vector error correction model (VECM) to perform Granger causality tests. Thus, we overcome the problem of short data span for individual countries. In other words, here we combine cross-sectional and time series data to improve the explanatory power of the cointegration and Granger causality test, respectively. We also assess the magnitude of the effect of the variables through variance decomposition. Based on the results, we offer suggestions and recommendations to economists and policymakers to enhance the effectiveness of environmental quality management policies.

The remainder of the paper is organised as follows. Section 2 reviews the related literature. Section 3 introduces the data and econometric methodology. Section 4 shows the empirical results. Section 5 discusses the results and provides policy implications and the last section summarises the findings.

2. Related Literature

The effects among economic growth, energy consumption, CO2, and FDI as well as the environmental implications have been examined in the related literature (Table 1). Studies have been conducted across countries and regions using different time periods and variables. This section deals with previous works studying those effects.

The world economy depends heavily on energy and the EU is no exception. Alam et al. (2012) found that energy is the indispensable force driving all economic activities. This implies that the more energy is consumed, the more the economic activities in the nation and thus the increase in economic growth. Researchers have found links between economic growth and energy consumption. For example, Masih & Masih (1996) used data from 1955–1990 for six Asian countries, Asafu-Adjaye (2011) used data from 1971–1995 for the Philippines and Dahmardeh et al. (2012) used data from 1980–2008 for 10 Asian developing countries. All these authors used panel cointegration tests to examine the relationship. Overall, their results provide empirical support for the nexus between energy consumption and economic growth. Farhani & Ben Rejeb (2012) used data from 1971–2005 to confirm the trend through cointegration, and the results of Granger causality tests showed that GDP contributes to energy consumption in low-income countries. A bidirectional causal relationship between economic growth and energy was also found by Menegaki & Ozturk (2013) for 26 European countries over 1975–2009 using a two-way fixed effects model. However, the survey by Ozturk et al.

(2010) on the energy consumption–economic growth nexus highlights that the literature has produced conflicting results, resulting in no consensus on the existence or on the direction of the causality. Matar & Bekhet (2015) showed that this causality can be affected by financial development (domestic credit to private sector). A strong relationship between economic growth and energy consumption has recently been found by Stjepanovic (2018) for 30 European countries using Eurostat data from 1994-2016.

Many studies have empirically examined the nexus between CO2 emissions (environmental pollution) and economic growth using the environmental Kuznets curve hypothesis. Most use CO2 as a dependent variable. For example, Azomahou et al. (2006) used a non-parametric kernel-based estimator to find the nexus between economic growth and CO2 emissions for a panel of 100 countries from 1960–1996. The results indicated the structural stability of the relationship. Another result from the top 70 countries based on variance decomposition also found a positive relationship between GDP and CO2 emissions from fossil fuels (Bacon et al., 2007). Jalil & Mahmud (2009) used data from 1995–2005 and employed an autoregressive distributed lag approach, providing evidence of a quadratic relationship between income and CO2 emissions. Ozturk & Acaravcci (2010) also investigated the long-run causal relationships among economic growth, energy consumption, CO2 emissions and employment in Turkey using data from 1968–2005 and the autoregressive distribution lag bounds method of cointegration. The results showed that neither energy consumption per capita nor CO2 emissions causes GDP growth. Yet, the employment ratio was reported to have a causal relation with GDP per capita (Park & Hong, 2013). Yuan et al. (2010) examined the relation between China’s economic growth and energy consumption using grey incidence analyses and data from 1980–2007. The results differed by period, although there was some positive effect on GDP. On the contrary, Arouri et al. (2012) used panel unit root tests and the cointegration technique to determine the relationship between energy consumption and real GDP for 12 North Africa and Middle Eastern countries from 1981–2005. Their results indicated that there was a significant impact of real GDP on energy consumption and CO2 emissions. More research on the relationship between GDP and CO2 emissions can be traced to many other researchers (Saboori et al., 2012). For example, Zambrano-Monserrate et al. (2016) employed ARDL (Autoregressive distribution lag model) and VECM to explore the links between economic growth and environmental degradation in Brazil using data from 1971-2011. Their results indicate the long-run relationship between CO2 and economic growth. This finding has recently been confirmed by a systematic meta-analysis (Mardani et al., 2019). Aye & Edoja (2017) employed a dynamic panel threshold framework to demonstrate that the correlation between CO2 and economic growth is positive for developed economies (in the high growth regime), whereas negative for developing economies (in the low growth regime).

FDI is made up of a bundle of the technological transfer of capital inflows and knowledge (Balasubramanyam et al., 1996). It can be deduced from this assertion that the contributions of FDI to economic growth are numerous. Other scholars regard its impact as contradictory because it also creates environmental setbacks, as it obstructs the effective allocation of resources and hence economic growth (Boyd & Smith, 1992). Theoretical studies of the positive effect of FDI on economic growth include that of Marwah & Tavakali (2004). They used data from 1979–1998 on Thailand, Malaysia, Indonesia and the Philippines to study the effect of FDI on economic growth, finding a positive correlation in those countries. Li & Liu (2005) used single and simultaneous equation techniques and found a growing relationship between FDI and economic growth using panel data from 1970–1999 for 84 countries. The results indicated a positive effect of FDI on economic growth. Vu et al. (2008) used an augmented production function specification as well as regression methods to study sector-specific FDI inflows for Vietnam and China over 1990–2002. Their conclusion was that FDI has a positive and direct effect on economic growth. Moreover, Alfaro et al. (2006) employed an extended dataset and found that the same increase in FDI, regardless of the region, generates three times more additional growth in financially well-developed countries than financially poorly developed countries. Upadhyaya et al. (2007) used panel and generalised least squares methods and found a similar result in his research. In addition, Matar (2016) reported a unidirectional causality between FDI and economic growth in Jordan over the period 1976-2011. In contrast, no positive effect of FDI on economic growth was reported by Bermejo Carbonell & Werner (2018) for Spain using data from 1984-2010. The negative effect of CO2 emissions on FDI was observed for Chinese provinces by Wang et al. (2019), suggesting that less stringent environmental regulations attract FDI.

Net exports signify the total exports exceeding the total imports of a domestic country. The role of net exports in the economy is significant. Jiang (2017) provided evidence of a negative relationship between GDP growth and net exports. In other words, net exports impede economic growth in China. The study by Subasat (2002) examined the effect of net exports on economic growth in middle-income countries, finding a positive effect of net exports on economic growth. Dritsakis (2004) assessed the relationships among economic growth, net exports and investment in Bulgaria and Romania. He employed a cointegration approach and the results indicated that net exports have a positive effect on GDP. Akalpler & Shamadeen (2017) investigated the effect of net exports on economic growth in the US using quarterly data from 1970-2015, suggesting a long-run positive effect. The positive effect of exports on financial development and energy consumption in Jordan was observed by Matar & Bekhet (2015).

Evidence of economic growth promoting employment was found by Seyfried (2011). He used some states in the US and data from 1990–2003, finding evidence of the immediate impact of economic growth on employment and showing that its effects continued for several quarters in the states considered. Choi (2007) also used an equilibrium labour market model to assess the employment effect of economic growth and the results indicated that labour supply based on wages is a vital determinant of the employment effect on economic growth. Herman (2011) also investigated the impact of economic growth on employment in EU countries. The results portrayed a problem, particularly in Central and Eastern European countries in that they have a low ability to create employment, whereas their economies keep growing (Herman, 2011). He also suggested that human capital development increases employment and hence contributes to economic growth. Kapsos (2006) assessed how employment intensity varies with economic output or the elasticity of employment using data from 1991 to 2003 for 160 economies (cross-country). His results indicated that every 1% increase in GDP growth raises employment growth by between 0.30% and 0.38%. Overall, the literature suggests a reciprocal effect between economic growth and employment (Burggraeve et al., 2015).

Table 1

The above literature indicates strong interactions among energy consumption, CO2 and economic development. The strengths and directions of these interactions seem to be related to different economic environments. In order to determine their role in the nexus among energy consumption, CO2 emissions and economic development, we need to examine the combined effects of economic development factors in different economic environments. This represents the main motivation for this study.

3. Data

For the empirical study, we collected annual time series data from the World Bank database that cover 1990 to 2015. The economic variables used are GDP (measured in millions of current US dollars), energy consumption (measured in millions of kg of oil equivalent per capita), CO2 emissions (measured in millions of metric tons per capita), employment in industry (percentage of total employment), net exports (current US dollars) and FDI (measured as the balance of payments, current US dollars). The sample of EU countries includes Croatia, Czech Republic, Cyprus, Hungary, Poland, Slovakia and Slovenia for the new countries. The old countries comprise Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. Thus, the panel data for the new and old countries consisted of 208 and 390 observations, respectively. The summary statistics of the time series variables are presented in Table 2.

Table 2

4. Econometric Model

Based on the literature and findings in energy economics, it is prudent to form long-run relationships among energy consumption (EC), CO2 emissions, employment (EMP), net exports (NEXP), FDI and economics growth (GDP) in a linear quadratic form to test the validity of the interactions among those variables using a cointegration approach. Considering the recent panel data, the issue of short data span for individual countries was addressed. Hence, the explanatory power of the employed econometric model is improved.

We began by estimating the panel unit root test to determine the stationarity of the individual variables. To address the issue of cross-sectional dependence in the panel data, we first performed the residual cross-sectional dependence (CD) test of Pesaran (2004), which is based on the Lagrange Multiplier (LM) statistic given as the sum of pairwise correlation coefficients of the residuals. Then, the CIPS (cross-sectionally augmented Im–Pesaran–Shin) panel unit root test was used to overcome the problem of CD in the data (Pesaran, 2007). This test was also preferred because it allows for heterogeneous autoregressive coefficients. Note that the CIPS test is calculated as the cross-section average of the CADF (cross-sectionally augmented Dickey-Fuller) when used to each cross-section unit.

We then estimated the Vector Autoregression (VAR) model by using the stationary series. We determined the lag length by considering the modified Akaike information criterion (AIC) and Schwarz criterion (SC) to perform the combined Fisher-Johansen panel cointegration test (Maddala & Wu, 1999) in the next step. The combined Fisher-Johansen panel cointegration test was used due to its capacity to detect more than one cointegrating relationships (Mishra & Sharma, 2010). This is an important advantage over the residual-based Pedroni’s test. The used cointegration test depends on the error correction model symbolising the VAR model presented below:

$$Y_{i,t} = \alpha_i + \sum_{j=1}^{q} \pi_j X_{i,t-j} + \varepsilon_{i,t}, \tag{1}$$

where $Y_{i,t}$=[GDP, EC, CO2, FDI, EMP, NEXP], i is the index for country, $i = 1, 2, \ldots , N$, t is time, $t = 1, 2, \ldots , T$, π_j are coefficients representing cointegrating relations, α_i is a constant term and $\varepsilon_{i,t}$ is white noise.

The number of cointegration vectors among the variables is assessed by determining the rank of two criteria, namely the Fisher trace and maximum eigenvalue statistics. The combined Fisher-Johansen panel cointegration test is only employed to test whether the variables are integrated and does not show the trend or direction of causality among the variables. Based on the combined Fisher-Johansen panel cointegration test, if the variables are cointegrated, they may have short- or long-run causality.

To investigate the direction of the short- and long-run causality among the six variables, a panel VECM (Pesaran et al., 1999) was specified in two steps as recommended in earlier studies (Kasman & Duman, 2015). First, the long-run parameters were estimated using the FMOLS (fully modified ordinary least squares) method (Pedroni, 2000) for the following model:

$$Y_{i,t} = \alpha_i + \sum_{k=1}^{n} \beta_k x_{i,t}^{k} + \varepsilon_{i,t}, \tag{2}$$

where β_k is the long-run coefficient for the k-th variable x^k. We used FMOLS because it allows for heterogeneity among the cross-sections of panel. In addition, both simultaneity bias and residual correlation can be corrected using FMOLS (Kasman & Duman, 2015). The panel FMOLS estimator can be defined as follows:

$$\hat{\beta}^{*}_{FMOLS} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T}\left(X_{i,t} - \bar{X}_i\right)^2\right)^{-1}\left(\sum_{t=1}^{T}\left(X_{i,t} - \bar{X}_i\right)Y_{i,t}^{*} - T\hat{\gamma}_i\right)\right], \tag{3}$$

where $Y_{i,t}^{*} = Y_{i,t} - \bar{Y}_i - (\hat{\Omega}_{2,1,i}/\hat{\Omega}_{2,2,i})\Delta X_{i,t}, \hat{\gamma}_i = \hat{\Gamma}_{2,1,i} + \hat{\Omega}_{2,1,i}^{0} - (\hat{\Omega}_{2,1,i}/\hat{\Omega}_{2,2,i})(\hat{\Gamma}_{2,2,i} + \hat{\Omega}_{2,2,i})$, Ω is the long-run covariance matrix, $\hat{\Omega}_i^0$ is the contemporaneous covariance, and Γ_i is the weighted sum of autocovariances.

To investigate the directions of the cointegrating relationships among variables, the short- and long-run Granger causality test is given as follows:

$$\begin{aligned}\Delta GDP_{i,t} = \alpha_{1,i} &+ \sum_{j=1}^{q}\beta_{1,1,i,j}\Delta EC_{i,t-j} + \sum_{j=1}^{q}\beta_{1,2,i,j}\Delta CO2_{i,t-j} + \sum_{j=1}^{q}\beta_{1,3,i,j}\Delta FDI_{i,t-j} + \\ &\sum_{j=1}^{q}\beta_{1,4,i,j}\Delta EMP_{i,t-j} + \sum_{j=1}^{q}\beta_{1,5,i,j}\Delta NEXP_{i,t-j} + \gamma_{1,i}ECT_{i,t-1} + \varepsilon_{1,i,t},\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta EC_{i,t} = \alpha_{2,i} &+ \sum_{j=1}^{q}\beta_{2,1,i,j}\Delta GDP_{i,t-j} + \sum_{j=1}^{q}\beta_{2,2,i,j}\Delta CO2_{i,t-j} + \sum_{j=1}^{q}\beta_{2,3,i,j}\Delta FDI_{i,t-j} + \\ &\sum_{j=1}^{q}\beta_{2,4,i,j}\Delta EMP_{i,t-j} + \sum_{j=1}^{q}\beta_{2,5,i,j}\Delta NEXP_{i,t-j} + \gamma_{2,i}ECT_{i,t-1} + \varepsilon_{2,i,t},\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta CO2_{i,t} = \alpha_{3,i} &+ \sum_{j=1}^{q}\beta_{3,1,i,j}\Delta GDP_{i,t-j} + \sum_{j=1}^{q}\beta_{3,2,i,j}\Delta EC_{i,t-j} + \sum_{j=1}^{q}\beta_{3,3,i,j}\Delta FDI_{i,t-j} + \\ &\sum_{j=1}^{q}\beta_{3,4,i,j}\Delta EMP_{i,t-j} + \sum_{j=1}^{q}\beta_{3,5,i,j}\Delta NEXP_{i,t-j} + \gamma_{3,i}ECT_{i,t-1} + \varepsilon_{3,i,t},\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta FDI_{i,t} = \alpha_{4,i} &+ \sum_{j=1}^{q}\beta_{4,1,i,j}\Delta GDP_{i,t-j} + \sum_{j=1}^{q}\beta_{4,2,i,j}\Delta EC_{i,t-j} + \sum_{j=1}^{q}\beta_{4,3,i,j}\Delta CO2_{i,t-j} + \\ &\sum_{j=1}^{q}\beta_{4,4,i,j}\Delta EMP_{i,t-j} + \sum_{j=1}^{q}\beta_{4,5,i,j}\Delta NEXP_{i,t-j} + \gamma_{4,i}ECT_{i,t-1} + \varepsilon_{4,i,t},\end{aligned} \tag{7}$$

$$\Delta EMP_{i,t} = \alpha_{5,i} + \sum_{j=1}^{q}\beta_{5,1,i,j}\Delta GDP_{i,t-j} + \sum_{j=1}^{q}\beta_{5,2,i,j}\Delta EC_{i,t-j} + \sum_{j=1}^{q}\beta_{5,3,i,j}\Delta CO2_{i,t-j} +$$

$$\sum_{j=1}^{q} \beta_{5,4,i,j} \Delta FDI_{i,t-j} + \sum_{j=1}^{q} \beta_{5,5,i,j} \Delta NEXP_{i,t-j} + \gamma_{5,i} ECT_{i,t-1} + \varepsilon_{5,i,t}, \quad (8)$$

$$\Delta NEXP_{i,t} = \alpha_{6,i} + \sum_{j=1}^{q} \beta_{6,1,i,j} \Delta GDP_{i,t-j} + \sum_{j=1}^{q} \beta_{6,2,i,j} \Delta EC_{i,t-j} + \sum_{j=1}^{q} \beta_{6,3,i,j} \Delta CO2_{i,t-j} + \sum_{j=1}^{q} \beta_{6,4,i,j} \Delta FDI_{i,t-j} + \sum_{j=1}^{q} \beta_{6,5,i,j} \Delta EMP_{i,t-j} + \gamma_{6,i} ECT_{i,t-1} + \varepsilon_{6,i,t}, \quad (9)$$

where Δ is the first difference operator, $\beta_{i,j}$ are coefficients representing short-run cointegrating relations, γ_i are coefficients representing long-run cointegrating relations and ECT is the error correction term.

We also determined the long-run relationship by using an error correction test. This operates on the premise that if GDP, energy consumption, CO2 emissions, FDI, employment and net exports are cointegrated, then at least one of the error correction tests contains a negative coefficient and ought to be significantly non-zero. On the contrary, short-run causality is also estimated using the standard Wald test (by testing H_0: $\beta_{i,j}=0$) as well as the lags of each of the explanatory variables in each equation from the VECM.

For instance, when we accept the first null hypothesis of Eq. (4), it signifies that energy consumption per capita does not Granger cause GDP per capita in the short run. On the contrary, if we reject the null hypothesis and accept the alternative hypothesis in Eq. (4), it means that energy consumption per capita can Granger cause GDP per capita. All these are based on the *P*-value. This is also applicable to all the other variables. Further, the Granger causality test only provides evidence of causality among the variables but not the explicit magnitude of the impact from one variable to another. Hence, we used variance decomposition analyses based on the Cholesky decomposition technique (Pesaran & Shin, 1998) in the VECM to supply the quantitative intensity of the causality among the variables. In other words, we estimated this by employing the impulse response function to map out the intensity of the shock from one endogenous variable to the other. Within the variance decomposition structure, a shock to one variable not only influences that variable but also passes onto all the other endogenous variables in the dynamic structure of the model.

5. Empirical Results

Table 3 reports the results of the residual CD test using three statistics, namely Breusch-Pagan LM, Pesaran scaled LM and Pesaran CD. The results indicate the presence of cross-sectional dependence (the cross-sectional independence is strongly rejected at $P=0.01$). To handle the cross-sectional dependence, we tested for the unit root of the variables using the CIPS test. The outcomes of the test are presented in Table 4 and Table 5. The results show that all the variables are non-stationary (with or without trend) at the level of $P=0.05$ critical value. Except FDI, which was stationary, the rest of the variables became stationary after the first difference. In other words, they were cointegrated. To estimate if there is cointegration among the variables, we employed the combined Fisher-Johansen panel multivariate cointegration test. Before performing the test, we chose the optimum lag length necessary for the cointegration test. Based on the minimum AIC and SC through the estimation of the unconstrained VAR model for the first difference of the six variables under study, we obtained a lag length equal to three. At this point, we assumed that the data contained deterministic trends but the cointegration equations included intercepts. We selected this design because the unit root test of the six variables exhibited no common deterministic trend. Therefore, the cointegration rank of the variables was estimated by means of the maximum eigenvalue and trace test statistics.

Table 4

Table 5

The outcome of the combined Fisher-Johansen panel cointegration test is shown in Table 6. The null hypothesis here is no cointegration. For the old EU countries and no cointegrating equations (no. of CEs = 0), the value of the trace test was equal to 716.1 and that of the maximum eigenvalue test was 645.1. Therefore, the null hypothesis $r_0 \leq 0$ was rejected at both $P=0.05$ and $P=0.01$. The null hypothesis $r_0 \leq 1$ was also rejected at $P=0.05$ and $P=0.01$, with a trace test value of 338.0 and a maximum eigenvalue test of 184. Similarly, the null hypotheses $r_0 \leq 2$, $r_0 \leq 3$ and $r_0 \leq 4$ were rejected at $P=0.05$.

Table 6

The same analyses were applied to the outcomes of the eight new EU countries. The combined Fisher-Johansen panel cointegration test provided five cointegrating equations at $P=0.01$. Hence, this shows the existence of a cointegration relationship between GDP (economic growth) and energy consumption, CO2 emissions, employment, FDI and net exports. Summing up the results of this test, support was provided for the long-term relationships among the six variables for both old and new EU countries.

The results of the FMOLS method for the models represented by Eq. (2) are reported in Table 7 and Table 8. For the 15 old EU countries, the main results indicate positive and significant long-run bidirectional relationships between (1) GDP and energy consumption, (2) energy consumption and CO2 emissions, (3) employment and CO2 emissions, (4) net exports and CO2 emissions, and (5) GDP and net exports. The results further indicate that there is a negative relationship between GDP and CO2 emissions. However, given the poor explanatory power of the FMOLS model for FDI, strong inferences could not be drawn for FDI determinants. A similar problem arises in the FDI and net export models for the eight new EU countries (Table

8). The results in Table 8 indicate that there is a positive and significant relationship between energy consumption and CO2 emissions.

Table 7

Table 8

While the result of the combined Fisher-Johansen panel cointegration test refers to Granger causality, it does not show the intensity of the direction of the relation. We found short- and long-run causality among the variables for both the 15 old and the eight new EU countries using the VECM, as reported in Table 9 and Table 10. The VECM's estimated equations are from Eqs. (4) – (9). This was estimated for a period of lag selection based on the AIC and SC.

For the old EU countries, the results in Table 9 indicate that there is a short-run bidirectional causality (also termed weak Granger causality) between (1) GDP and energy consumption, (2) GDP and CO2 emissions, (3) energy consumption and CO2 emissions, (4) net export and CO2 emissions, (5) net export and FDI, and (6) employment and FDI. The results for the new EU countries in Table 10 indicate that there are short-run bidirectional panel causalities between (1) energy consumption and CO2 emissions, (2) employment and energy consumption, and (3) employment and FDI. In addition, there is a unidirectional panel causality running from GDP to energy consumption and CO2 emissions, respectively. Note that the short-run causality was estimated based on the joint significance of the coefficients of the lagged terms or individual independent variables in Eqs. (4) – (9).

As for the long-run causal relationships, we investigated the statistical significance of the ECT coefficients in Eqs. (4) – (9). Table 9 and Table 10 show that the estimated coefficients were equal to -0.16 and -0.23 at P=0.01 for GDP for both the old and the new EU countries, respectively. Similarly, energy consumption had coefficients of -0.36 and -0.49 at P=0.01 for both the old and the new EU countries, respectively. The same analyses were applied to the other variables. The results indicate statistically significant coefficients for GDP, energy consumption, CO2 emissions, FDI and net export, suggesting that these five variables are important for the long-run correction mechanism. In other words, these results indicate long-run bidirectional causal relationships between these variables for both the old and new EU countries. To put it another way, no long-run effect runs from the other variables to employment in the EU countries.

Table 9

Table 10

The outcomes of the variance decomposition in the 15 old EU countries are presented in Fig. 1. They indicate that 77.80% of GDP is explained by its own shocks. The contribution to economic growth by the other variables is as follows: CO2 emissions, employment, energy consumption, net exports and FDI contribute 9.28%, 5.98%, 5.11%, 1.04% and 0.7%, respectively. The results for energy consumption point out that 66.51% is accounted for by its own shock, whereas CO2 emissions, GDP, FDI, net exports and employment contribute 13.12%, 7.5%, 5.74%, 4.5% and 2.94%, respectively. In addition, the result for CO2 emissions reveals that 44.50% is caused by its own shock, whereas energy consumption, FDI, net exports, employment and GDP contribute 34.85%, 9.14%, 5.56%, 3.39% and 2.54%, respectively. For FDI, 35.91% is caused by its own shock, whereas the contributions of CO2 emissions, employment, energy consumption, net exports and GDP are equal to 33.36%, 19.13%, 6.19%, 4.49% and 0.89%, respectively. The same analyses are applied to the other variables.

Fig. 1

The outcomes of the variance decomposition approach in the eight new EU countries are shown in Fig. 2. They reveal that 45.52% of GDP was caused by its own shocks. Employment contributed to economic growth by 44.18%. The contribution of the remaining variables was less than 5%. The result for energy consumption indicates that 33.45% of its change was produced by its own shock, while employment contributed to it even more at 55.57%. For CO2 emissions, 40.90% was accounted for by its own shock, whereas energy consumption and employment were the most important contributors with 35.03% and 18.41%, respectively. Finally, 65.26% of FDI was triggered by its own shock, and the contribution of employment was 27.99%.

Fig. 2

Regarding the impulse response function in Fig. 3 and Fig. 4, the effect of one variable influences the other variables. The assessment of GDP indicates that it initially rises, then falls, stabilises at a point in time and then decreases again. Most of these fluctuations stem from energy consumption, CO2 emissions and employment for the 15 old EU countries (Fig. 3). An assessment of GDP in the eight new EU countries indicates that it initially rises and then decreases (Fig. 4). In a similar fashion to the old EU countries, all those fluctuations stem from energy consumption, CO2 emissions, FDI and employment.

Fig. 3

Fig. 4

The remaining impulse response functions are presented in Appendix A and Appendix B. Further, the response to energy consumption in the old EU countries first increases, then falls, stagnates and decreases by a small margin. This is also due to a shock from the other variables, especially energy consumption and CO2 emissions, whereas in the new EU countries, energy consumption initially rises and then falls. All these fluctuations stem from employment and GDP. Moreover, the response to CO2 emissions also increases, then changes and continuously decreases in the old EU countries due to the shocks from energy consumption and employment. The response to CO2 emissions also increases, then falls marginally, stabilises and decreases for the new EU countries. This fluctuation also emanates from energy consumption and employment. The rate of CO2 emissions between the two regions is different since the variance decomposition between the two regions has a different pattern of fluctuations. The fluctuation in terms of the impulse response of employment was mostly caused by CO2 emissions, GDP and net exports.

6. Discussion and Policy Implications

On the whole, the responses of GDP, energy consumption, FDI and net exports kept decreasing over time, whereas the responses of CO2 and employment had an unstable pattern of fluctuations, as they declined from the initial period, became stable and decreased at a certain point in time. This result is not startling, especially since CO2 emissions, employment and energy consumption have a greater influence on GDP because it is assumed that economic growth usually results in CO2 emissions, creating employment coupled with high energy consumption. The same results were confirmed by Ozturk & Acaravci (2010) for CO2 emissions and economic growth. Economic growth tends to increase employment and the same results were confirmed by Seyfried (2011), Kapsos (2006) and Herman (2011). Moreover, the EU region continues to experience a rise in the number of services and manufacturing industries with the ability to employ many workers compared with other sectors such as agriculture. Comparably, manufacturing and services industries have contributed to shrinking the high unemployment rate, particularly since the economic crises, by absorbing large segments of the labour force in the region. In effect, the activities and training of those industries have improved labour productivity as well as increased aggregate economic growth. However, it should be noted that the positive effect between employment on economic growth was observed only in the short run, implying a low ability to promote employment in the long run in the region (Herman, 2011). To overcome this problem, policymakers should revise their policies to promote the skills of employees. They should help academic institutions such as universities and vocational institutions persistently redesign their curricula to meet the current needs of the job market for the manufacturing and services industries. They should also assist start-up enterprises or institutions through access to credit. The governments of individual EU countries should help minimise job-related illness and ensure that the psychological health of workers is strengthened through occupational safety and health.

We also found the positive effect of FDI on economic growth, which corroborates previous literature (Pelinescu & Radulescu, 2009; Ibrahim & Muthusamy, 2014; Jude & Levieuge, 2015; Trojette, 2016). This finding can be explained by the favourable business environment in the EU, including the availability of efficient human capital, technology, a conducive business climate and the training of the labour force on how to use these technologies in the region (Armeanu et al., 2018). To raise economic growth, EU countries should continue to restructure their FDI policies to attract the right type of FDI, especially from both the services and the manufacturing sectors of their economies. They should also adopt a policy to keep modernising state enterprises with the current trend of technological advancement and train employees on technological advancement and skills. This will undoubtedly lead to long-term economic growth.

On the contrary, net exports stimulating economic growth is not a shocking result. The hypothesis confirmed this result in the long run, and it is simple and reasonable to understand due to its strong theoretical foundation, including the Heckscher-Ohlin's theory of international trade and more efficient allocation of resources favouring export-oriented industries (Akalpler & Shamadeen, 2017). An increase in net exports usually signifies more output from factories; hence, industrial facilities as well as more labour force are employed to ensure the continuous running of factories. Indeed, EU has strong ties with trading partners globally as one of the most open economies in the world and, at the same time, keeps boosting the manufacturing and services sectors of its economies. In essence, this induces economic growth. To sustain this, policymakers should also control domestic consumption so that more output can be exported. Individual countries and the EU should also implement new trade agreements and keep strengthening their trade ties with other countries.

The more energy consumed, the more CO2 is emitted into the environment (Halicioglu, 2009). This was also observed from our variance decomposition analyses, suggesting a long-run bidirectional relationship between energy consumption and CO2 emissions in both new and old EU countries. These results is consistent with feedback hypothesis of Kasman & Duman (2015) and Dogan & Aslan (2017). Hence, our study suggests that the policy makers should encourage energy-efficiency policies, such as financial incentives, market-oriented instruments, regulations or energy audits. Increasing public awareness of energy efficiency though information campaigns is another recommended policy measure.

Another question of energy economists is whether energy consumption affects the economy. The results for energy consumption contradict those of neoclassical growth models (Harod–Domor or Solow–Swan), which stipulate that energy is neutral to the economic growth process. Their model places much priority on capital, labour and land as the factors of production, which increase the output of the economy (Skeer & Wang, 2007). However, our results concur with the findings of Alam et al. (2012), Kasman & Duman (2015) and the ideas of ecologist economists such as Pokrovski (2003). They posited that energy has a significant role in the production process as the substitute of labour resource, thus representing endogenous technological change in economic growth models (Pokrovski, 2003). In a similar manner, Ghali & El-Sakka (2004) claimed that inputs such as capital and labour cannot perform without the use of energy in combination. Consequently, energy serves as a basic input for the value creation process and is pivotal for economic growth. On the one hand, our results support the conservation hypothesis (unidirectional causality running from economic growth to energy consumption) for the new EU countries, implying that energy reduction policies has no adverse effect on economic growth in those countries. On the other hand, the feedback hypothesis (bidirectional causality) was confirmed for the old EU countries, suggesting a complementary relationship between energy consumption and economic growth. In contrast to the previous literature supporting the conservation hypothesis in the EU countries (Dogan & Aslan, 2017), our findings suggest differences between the old and new EU countries, thus providing additional insight into the relationship between energy consumption and economic growth in the region.

We also witnessed that, in the short run, CO2 emissions affect GDP in both the old and new EU member countries. However, the negative bidirectional relationship was only confirmed for the 15 old EU countries. This finding corroborates the feedback hypothesis (Dogan & Aslan, 2017). This implies that there are differences in CO2 emissions between the two regions. The same result is also declared by the result of the variance decomposition. Therefore, these differences are ascribed to energy use intensity, differences in fuel prices in the individual countries, the fuel mix from 2001–2017 (Eurostat, 2018), interregional differences in economic growth and attitudes in dealing with carbonisation. In addition, structural differences that comprise the increase in population (resulting from immigration) and the fast rates of economic growth and technology spillover lend credence to the disparity in CO2 emissions (González et al., 2014). Indeed, the economic disparities have been considered in the EU effort to reduce GHG emissions, allowing EU countries with a lower GDP to increase emissions compared to 2005 (Delbeke & Vis, 2015). On the contrary, relatively rich EU countries have to reduce emissions to meet the EU commitments. Our results provide empirical support to this strategy. Specifically, a policy to reduce CO2 emissions is laudable because when CO2 emissions rise (fall), economic growth increases (slows). This holds despite the recent speculation that the trend of CO2 emissions in the region has reduced. In addition, policymakers and economic planners should keep on modifying their environmental tax and emission trading schemes to continue to control emissions. The EU as well as individual countries should keep revising their policies to meet their emission reduction targets to match the current trend of economic growth. They should also institute transparency, accountability and compliance schemes that should not be used as a punitive measure but rather to understand which member countries are off-track and put them back on track. The EU and its member countries should also continue to monitor baseline CO2 emissions, especially the use of technological growth development including automobiles, fluorinated GHG and carbon capture and storage devices to ensure continuous abatement. Finally, the EU must go beyond the proposed current policy as well as promote energy security and lessen air pollution by negotiating with the Technology Executive Committee (Suzuki, 2015).

Further, we observed that FDI does not contribute to the environmental problem (CO2 emissions), which is in contrast to the findings of Zheng & Sheng (2017) for China and Kocak & Sarkgunesi (2018) for Turkey. This can be attributed to higher environmental standards and strict environmental regulations in the EU countries (Seker et al., 2015). On the contrary, our results suggest that there is no causality between FDI and economic growth. This is consistent with the finding of Bermejo Carbonell & Werner (2018) for Spain, suggesting that we can generalize this finding for the EU region. This can be explained by the crowding-out effect of FDI on domestic investment, implying that policies for attracting FDI cannot be advised.

7. Conclusion

This study investigated the dynamic causal relationships among economic growth, energy consumption, CO2 emissions, employment, FDI and net exports in the 15 old and eight new EU countries. Compared with previous studies, the combined effects of economic development factors on energy consumption and CO2 emissions in different economic environments are of particular interest. Notwithstanding, it provides evidence on the dynamic interactions of the variables. The results confirm the existence of at least a long-run equilibrium relationship between economic growth and energy consumption, CO2 emissions, FDI and net exports. There exists bidirectional causality among those variables except for employment in both the old and new EU countries. In the short run, our results indicate bidirectional causality among GDP, energy consumption and CO2 emissions in the old EU countries. On the contrary, unidirectional causalities were found from GDP to energy consumption and CO2 emissions in the new EU countries. On the whole, and unlike the long run, FDI, employment and net exports-led growth hypotheses were not supported for the region in the short run.

Finally, several limitations of this study need to be mentioned. Some variables that might have significant effect on environmental quality were not considered, such as R&D level or population density (Zhang et al., 2019). In a similar fashion, the effect of economic development on financial markets can be considered (Bekhet & Matar, 2012). Therefore, the proposed model can be further extended by incorporating those variables. An investigation of the interactions among energy consumption, CO2 emissions and economic development in different economy sectors could be another promising direction for future work. Another limitation might be the focus on two categories of EU countries, rather than investigating the interactions at the country level. This was mainly due to the short data span for individual countries. Hence, it would be beneficial to investigate the country-level interactions when a longer time series will be available.

References

[1] Ajmi AN, Hammoudeh S, Nguyen DK, & Sato JR (2015). On the relationships between CO2 emissions, energy consumption and income: the importance of time variation. Energy Econ, 49, 629–638.

[2] Akalpler E, & Shamadeen B (2017). The role of net export on economic growth in United States of America. J Appl Econ Sci, 12(3), 772–781.

[3] Alfaro L, Chanda A, Kalemli-Ozcan S, & Sayek S (2006). How does foreign direct investment promote economic growth? Exploring the effects of financial markets on linkages. Cambridge: National Bureau of Economic Research.

[4] Alam MJ, Begum IA, Buysse J, & Van Huylenbroeck G (2012). Energy consumption, carbon emissions and economic growth nexus in Bangladesh: Cointegration and dynamic causality analysis. Energy Pol, 45, 217–225.

[5] Alam MS (2006). Economic growth with energy. Boston: Northeastern University.

[6] Alshehry AS, & Belloumi M (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. Renew Sust Energy Rev, 41, 237–247.

[7] Amri F (2017). Intercourse across economic growth, trade and renewable energy consumption in developing and developed countries. Renew Sustain Energy Rev, 69, 527–534.

[8] Ang JB (2008). Economic development, pollutant emissions and energy consumption in Malaysia. J Pol Model, 30(2), 271–278.

[9] Apergis N, & Payne JE (2010a). The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states. Energy Pol, 38(1), 650–655.

[10] Apergis N, & Payne JE (2010b). Renewable energy consumption and economic growth: evidence from a panel of OECD countries. Energy Pol 2010;38(1);656–660.

[11] Aqeel A, & Butt MS (2001). The relationship between energy consumption and economic growth in Pakistan. Asia-Pacif Develop J, 8(2), 101–110.

[12] Armeanu D, Vintilă G, & Gherghina Ş (2018). Empirical study towards the drivers of sustainable economic growth in EU-28 countries. Sustainability, 10(1), 4.

[13] Arouri MEH, Youssef AB, M'henni H, & Rault C (2012). Energy consumption, economic growth and CO2 emissions in Middle East and North African countries. Energy Pol, 45, 342–349.

[14] Asafu-Adjaye J (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Econ, 22(6), 615–625.

[15] Aslan A, Kum H, Ocal O, & Gozbasl O (2013). Energy consumption and economic growth: evidence from micro data. ASBBS Proc, 20(1), 280.

[16] Atici C (2009). Carbon emissions in Central and Eastern Europe: environmental Kuznets curve and implications for sustainable development. Sustain Develop, 17(3), 155–160.

[17] Aye GC, & Edoja PE (2017). Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. Cogent Econ & Fin, 5(1), 1379239.

[18] Azam M (2016). Does environmental degradation shackle economic growth? A panel data investigation on 11 Asian countries. Renew Sustain Energy Rev, 65, 175–182.

[19] Azomahou T, Laisney F, & Van PN (2006). Economic development and CO2 emissions: a nonparametric panel approach. J Public Econ, 90(6–7), 1347–1363.

[20] Baek J (2015). Environmental Kuznets curve for CO2 emissions: the case of Arctic countries. Energy Econ, 50, 13–17.

[21] Balasubramanyam VN, Salisu M, & Sapsford D (1996). Foreign direct investment and growth in EP and IS countries. Econ J, 106(434), 92–105.

[22] Bartleet M, & Gounder R (2010). Energy consumption and economic growth in New Zealand: Results of trivariate and multivariate models. Energy Pol, 38(7), 3508–3517.

[23] Bekhet HA, & Matar A (2012). Causality of macroeconomic variables impacting the stock market index: Time series approach in Amman Stock Exchange. Conf for Asian Forum on Business Education (AFBE), UNITEN, Malaysia.

[24] Bekhet HA, Matar A, & Yasmin T (2017). CO2 emissions, energy consumption, economic growth, and financial development in GCC countries: Dynamic simultaneous equation models. Renew Sustain Energy Rev, 70, 117–132.

[25] Bermejo Carbonell J, & Werner RA (2018). Does foreign direct investment generate economic growth? A new empirical approach applied to Spain. Econ Geogr, 94(4), 425–456.

[26] Boyd JH, & Smith BD (1992). Intermediation and the equilibrium allocation of investment capital: Implications for economic development. J Monet Econ, 30(3), 409–432.

[27] Burggraeve K, de Walque G, & Zimmer H (2015). The relationship between economic growth and employment. Economic Review, (i), 32–52.

[28] Chandran VGR, & Tang CF (2013). The impacts of transport energy consumption, foreign direct investment and income on CO2 emissions in ASEAN-5 economies. Renew Sustain Energy Rev, 24, 445–453.

[29] Cheng BS, & Lai TW (1997). An investigation of co-integration and causality between energy consumption and economic activity in Taiwan. Energy Econ, 19(4), 435–444.

[30] Choi CK (2007). The employment effect of economic growth: Identifying determinants of employment elasticity, http://faculty.washington. edu/karyiu/confer/busan07/papers/choi.pdf; [accessed 13 February 2019]

[31] Çoban S, & Topcu M (2013). The nexus between financial development and energy consumption in the EU: A dynamic panel data analysis. Energy Econ, 39, 81–88.

[32] Copeland BR, & Taylor MS (2004). Trade, growth, and the environment. J Econ Liter, 42(1), 7–71.

[33] Dagher L, & Yacoubian T (2012). The causal relationship between energy consumption and economic growth in Lebanon. Energy Pol, 50, 795–801.

[34] Dahmardeh N, Mahmoodi M, & Mahmoodi E (2012). Energy consumption and economic growth: evidence from 10 Asian developing countries. J Basic Appl Sci Res, 2(2), 1385–1390.

[35] Delbeke J, & Vis P (Eds.) (2015). EU climate policy explained. Routledge.

[36] Dogan E, & Aslan A (2017). Exploring the relationship among CO2 emissions, real GDP, energy consumption and tourism in the EU and candidate countries: Evidence from panel models robust to heterogeneity and cross-sectional dependence. Renew Sustain Energy Rev, 77, 239–245.

[37] Dritsakis N (2004). Exports, investments and economic development of pre-accession countries of the European Union: an empirical investigation of Bulgaria and Romania. Appl Econ, 36(16), 1831–1838.

[38] Eden SH, & Jin JC (1992). Cointegration tests of energy consumption, income, and employment. Resour Energy, 14(3), 259–266.

[39] European Commission (2019). European Climate Change Programme, https://ec.europa.eu/clima/policies/eccp_en [accessed 13 February 2019].

[40] Eurostat (2018), Union européenne. Commission européenne. Energy, transport and environment indicators – 2018 edition. Office for Official Publications of the European Communities, Luxembourg.

[41] Bacon RW, Bhattacharya S, Damania R, Kojima M, & Lvovsky K (2007). Growth and CO2 emissions: how do different countries fare?. Environment Department Papers 113.

[42] Farhani S, & Ben Rejeb J (2012). Link between economic growth and energy consumption in over 90 countries. Tunisia: University of Sousse.

[43] Ghali KH, & El-Sakka MI (2004). Energy use and output growth in Canada: a multivariate cointegration analysis. Energy Econ 26(2), 225–238.

[44] González PF, Landajo M, & Presno MJ (2014). The driving forces behind changes in CO2 emission levels in EU-27. Differences between member states. Environ Sci Pol, 38, 11–16.

[45] Halicioglu F (2009). An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. Energy Pol, 37(3), 1156–1164.

[46] Herman E (2011). The impact of economic growth process on employment in European Union countries. Romanian Econ J, 14(42), 47–67.

[47] Ibrahim MS, & Muthusamy A (2014). Role of Foreign Direct Investment (FDI) in India’s Economic Development - An Analysis. J Int Relat Foreign Pol, 2(2), 101–113.

[48] Işik C, Kasımatı E, & Ongan S (2017). Analyzing the causalities between economic growth, financial development, international trade, tourism expenditure and/on the CO2 emissions in Greece. Energy Sourc, Part B: Econ, Plan Pol, 12(7), 665–673.

[49] Jalil A, & Feridun M (2011). The impact of growth, energy and financial development on the environment in China: a cointegration analysis. Energy Econ, 33(2), 84–291.

[50] Jalil A, & Mahmud SF (2009). Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. Energy Pol, 37(12), 5167–5172.

[51] Jiang Q (2017). Does exports promote the economic growth of China? A long-run view point. Int J Fin Res, 8(2), 64–74.

[52] Jude C, & Levieuge G (2015). Growth effect of FDI in developing economies: the role of institutional quality. Banque de France Working Paper, 559.

[53] Kapsos S (2006). The employment intensity of growth: Trends and macroeconomic determinants. Labor Markets in Asia; pp. 143–201. London: Palgrave Macmillan.

[54] Kasman A, & Duman YS (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. Econ Model, 44, 97–103.

[55] Kizilkaya O (2017). The impact of economic growth and foreign direct investment on CO2 emissions: the case of Turkey. Turkish Econ Rev, 4(1), 106–118.

[56] Koçak E, & Şarkgüneşi A (2018). The impact of foreign direct investment on CO2 emissions in Turkey: new evidence from cointegration and bootstrap causality analysis. Environ Sci Pollut Res, 25(1), 790–804.

[57] Kraft J, & Kraft A (1978). On the relationship between energy and GNP. J Energy Dev, 3(2), 401–403.

[58] Lean HH, & Smyth R (2010). CO2 emissions, electricity consumption and output in ASEAN. Appl Energy, 87(6), 1858–1864.

[59] Lee CC, & Chang CP (2008). Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. Resour Energy Econ, 30(1), 50–65.

[60] Li,X, & Liu X (2005). Foreign direct investment and economic growth: an increasingly endogenous relationship. World Dev, 33(3), 393–407.

[61] López-Menéndez AJ, Pérez R, & Moreno B (2014). Environmental costs and renewable energy: re-visiting the environmental Kuznets curve. J Environ Manag, 145, 368–373.

[62] Mabey N, & McNally R (1998). Foreign direct investment and the environment. World Wildlife Foundation.

[63] Maddala GS, & Wu S (1999). A comparative study of unit root tests with panel data and a new simple test. Oxford Bull Econ Stat, 61, 631–652.

[64] Makki SS, & Somwaru A (2004). Impact of foreign direct investment and trade on economic growth: Evidence from developing countries. Amer J Agric Econ, 86(3), 795–801.

[65] Mardani A, Streimikiene D, Cavallaro F, Loganathan N, & Khoshnoudi M (2019). Carbon dioxide (CO2) emissions and economic growth: A systematic review of two decades of research from 1995 to 2017. Sci Total Environ, 649, 31–49.

[66] Marwah K, & Tavakoli A (2004). The effect of foreign capital and imports on economic growth: Further evidence from four Asian countries (1970–1998). J Asian Econ, 15(2), 399–413.

[67] Masih AMM, & Masih R (1996). Electricity consumption, real income and temporal causality: results from a multi-country study based on cointegration and error–correction modeling techniques. Energy Econ, 18, 165–183.

[68] Matar A (2016). A dynamic equilibrium relationship between foreign direct investment, electrical power consumption, and gross domestic product in Jordan. Jordan J Econ Sci, 3(1), 13–29.

[69] Matar A, & Bekhet HA (2015). Causal interaction among electricity consumption, financial development, exports and economic growth in Jordan: Dynamic simultaneous equation models. Int J Energy Econ Pol, 5(4), 955–967.

[70] Mbarek MB, Ali NB, & Feki R (2014). Causality relationship between CO 2 emissions, GDP and energy intensity in Tunisia. Environ Dev Sustain, 16(6), 1253–1262.

[71] McAusland C (2008). Trade, politics, and the environment: Tailpipe vs. smokestack. J Environ Econ Manag, 55(1), 52–71.

[72] Melnyk LH, Kubatko OV, & Pysarenko S (2014). The impact of foreign direct investment on economic growth: case of post communism transition economies. Probl Persp Manag, 12, 17–24.

[73] Menegaki AN, & Ozturk I (2013). Growth and energy nexus in Europe revisited: evidence from a fixed effects political economy model. Energy Pol, 61, 881–887.

[74] Mishra RK, & Sharma C (2010). Real exchange rate behavior and optimum currency area in East Asia: Evidence from generalized purchasing power parity. Int Rev Fin Anal, 19(3), 205–213.

[75] Narayan PK, & Narayan S (2010). Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. Energy Pol, 38(1), 661–666.

[76] Neslen A (2015). Europe’s greenhouse gas emissions fall to record low, https//www.theguardian.com/ environment/2015/oct/20/europes; [accessed 13 February 2019]

[77] Niu S, Ding Y, Niu Y, Li Y, & Luo G (2011). Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries. Energy Pol, 39(4), 2121–2131.

[78] Odhiambo NM (2009). Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach. Energy Pol, 37(2), 617–622.

[79] Omri A (2013). CO2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. Energy Econ, 40, 657–664.

[80] Ozturk I, & Acaravci A (2010). CO2 emissions, energy consumption and economic growth in Turkey. Renew Sustain Energy Rev, 14(9), 3220–3225.

[81] Ozturk I, & Acaravci A (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ, 36, 262–267.

[82] Ozturk I, Aslan A, & Kalyoncu H (2010). Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. Energy Pol, 38(8), 4422–4428.

[83] Pao HT, & Tsai CM (2011). Multivariate Granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. Energy, 36(1), 685–693.

[84] Park J, & Hong T (2013). Analysis of South Korea’s economic growth, carbon dioxide emission, and energy consumption using the Markov switching model. Renew Sustain Energy Rev, 18, 543–551.

[85] Pedroni P (2001). Fully modified OLS for heterogeneous cointegrated panels. In: Nonstationary panels, panel cointegration, and dynamic panels, pp 93–130.

[86] Pelinescu E, & Radulescu M (2009). The impact of foreign direct investment on the economic growth and countries’ export potential. Romanian J Econ Forecast, 12(4), 153–169.

[87] Pesaran HH, & Shin Y (1998). Generalized impulse response analysis in linear multivariate models. Econ Letters, 58(1), 17–29.

[88] Pesaran MH, Shin Y, & Smith RP (1999). Pooled mean group estimation of dynamic heterogeneous panels. J Amer Stat Assoc, 94, 621–634.

[89] Pesaran MH (2004). General diagnostic tests for cross section dependence in panels. Cambridge Work Pap Econ, 0435(3), 1–39.

[90] Pesaran MH (2007). A simple panel unit root test in the presence of cross sectional dependence. J Appl Econom, 22, 265–312.

[91] Pokrovski VN (2003). Energy in the theory of production. Energy, 28(8), 769–788.

[92] Roinioti A, & Koroneos C (2017). The decomposition of CO2 emissions from energy use in Greece before and during the economic crisis and their decoupling from economic growth. Renew Sustain Energy Rev, 76, 448–459.

[93] Saboori B, Sulaiman J, & Mohd S (2012). Economic growth and CO2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. Energy Pol, 51, 184–191.

[94] Santos PG, Ribeiro AP, & Carvalho VM (2013). Export-led growth in Europe: Where and what to export?. FEP Working Papers, 479.

[95] Seker F, Ertugrul HM, Cetin M (2015). The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey. Renew Sust Energ Rev, 52, 347–356.

[96] Seyfried W (2011). Examining the relationship between employment and economic growth in the ten largest states. Southwestern Econ Rev, 32, 13–24.

[97] Skeer J, & Wang Y (2007). China on the move: Oil price explosion?. Energy Pol, 35(1), 678–691.

[98] Stern DI (1993). Energy and economic growth in the USA: a multivariate approach. Energy Econ, 15(2), 137–150.

[99] Stjepanović S (2018). Relationship between energy consumption and economic growth in 30 countries in Europe-panel. Ekonomski Pregled, 69(1), 43–57.

[100] Subasat T (2002). Does export promotion increase economic growth? Some cross-section evidence. Dev Pol Rev, 20(3), 333–349.

[101] Suzuki M. (2015). Identifying roles of international institutions in clean energy technology innovation and diffusion in the developing countries: matching barriers with roles of the institutions. J Cleaner Prod, 98, 229–240.

[102] Tang CF, & Tan BW (2015). The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. Energy, 79, 447–454.

[103] Tiba S, & Omri A (2017). Literature survey on the relationships between energy, environment and economic growth. Renew Sust Energ Rev, 69, 1129–1146.

[104] Trojette I (2016). The effect of foreign direct investment on economic growth: the Institutional threshold. Region et Dev, 43, 111–138.

[105] Upadhyaya KP, Pradhal G, Dhakal D, & Bhandari R (2007). Foreign aid, FDI and economic growth in East European countries. Econ Bulletin, 6(13), 1–9.

[106] Vu TB, Gangnes B, & Noy I (2008). Is foreign direct investment good for growth? Evidence from sectoral analysis of China and Vietnam. J Asia Pacif Econ, 13(4), 542–562.

[107] Wang ML, Wang W, Du SY, Li CF, & He Z (2019). Causal relationships between carbon dioxide emissions and economic factors: Evidence from China. Sustain Develop, doi: 10.1002/sd.1966.

[108] Wang SS, Zhou DQ, Zhou P, & Wang QW (2011). CO2 emissions, energy consumption and economic growth in China: A panel data analysis. Energy Pol, 39(9), 4870–4875.

[109] Yuan C, Liu S, Fang Z, & Xie N (2010). The relation between Chinese economic development and energy consumption in the different periods. Energy Pol, 38(9), 5189–5198.

[110] Zamani M (2007). Energy consumption and economic activities in Iran. Energy Econ, 29(6), 1135–1140.

[111] Zambrano-Monserrate MA, Valverde-Bajana I, Aguilar-Bohorquez J, & Mendoza-Jimenez MJ (2016). Relationship between economic growth and environmental degradation: Is there evidence of an environmental Kuznets curve for Brazil?. Int J Energy Econ Pol, 6(2), 208–216.

[112] Zhang J, Hassan ST, & Iqbal K (2019). Toward achieving environmental sustainability target in Organization for Economic Cooperation and Development countries: The role of real income, research and development, and transport infrastructure. Sustain Develop, doi: 10.1002/sd.1973.

[113] Zheng J, & Sheng P (2017). The impact of foreign direct investment (FDI) on the environment: market perspectives and evidence from China. Economies, 5(1), 8.

Table 1: List of earlier studies on interactions among studied indicators

Study	Period	Methodology	Country	Causality
Eden & Jin (1992)	1974-1990	cointegration, Granger causality	US	EC≠EMP
Cheng & Lai (1997)	1955-1993	cointegration, Granger causality	Taiwan	GDP→EC
Aqeel & Butt (2001)	1955-1996	cointegration, Granger causality	Pakistan	GDP→EC
Zamani (2007)	1967-2003	VECM	Iran	GDP↔EC
Ang (2008)	1971-1999	cointegration	Malaysia	long run: CO2≠GDP, EC≠CO2, short run: GDP→CO2, EC→CO2
Atici (2009)	1980-2002	OLS	CEE countries	EC→CO2
Apergis & Payne (2010a)	1992-2004	VECM	Commonwealth Independent States’ countries	EC↔CO2, GDP→CO2
Apergis & Payne (2010b)	1985-2005	panel cointegration, VECM	OECD countries	EMP→GDP, GDP↔EMP
Bartleet & Gounder (2010)	1960-2004	trivariate demand, multivariate production models, Granger causality	New Zealand	GDP→EC
Pao & Tsai (2011)	1980-2007, 1992-2007	panel cointegration	BRIC countries	FDI→CO2, EC→CO2, EC↔GDP, GDP→CO2, EC↔CO2
Jalil & Feridun (2011)	1953-2006	VECM causality cointegration analyses	China	EC→CO2, FDI→CO2
Dagher & Yacoubian (2012)	1980-2009	Hsiao Granger and Toda Yamamoto, VECM granger causality	Lebanon	long run: ECG↔EC, short run: ECG↔EC
Park & Hong (2013)	1991-2011	Markov switching model	South Korea	GDP↔CO2
Omri (2013)	1971-2006	VECM, Granger causality	Tanzania	EC→ECG
Ozturk & Acaravci (2013)	1990-2011	2SLS, 3SLS, panel GMM	Mena countries	GDP→CO2, EC→CO2
Chandran & Tang (2013)	1971-2008	panel cointegration, VECM, Granger causality	Indonesia Malaysia and Thailand	Indonesia, Malaysia: GDP↔CO2, Malaysia, Indonesia and Thailand: EC↔CO2,
Baek (2015)	1960-2010	cointegration	Canada, Northern EU countries	EC→CO2, GDP→CO2
Ajmi et al. (2015)	1960-2010	Granger causality	G-7 countries	Japan: GDP→EC, Italy: GDP→EC, GDP→CO2, Canada: EC→GDP, US: EC→CO2, France: EC→CO2, GDP→CO2
Alshehry & Belloumi (2015)	1971-2010	cointegration, VECM	Saudi Arabia	GDP→CO2, EC↔GDP
Kasman & Duman (2015)	1992-2010	panel cointegration, Granger causality	EU countries	GDP↔CO2, EC↔CO2, EC→GDP
Kasman & Duman (2015)	1992-2010	panel cointegration, FMOLS	candidate EU countries	short run: EC→CO2. long run: GDP↔EC, GDP↔CO2, CO2↔EC
Matar & Bakhet (2015)	1996-2011	ARDL, Granger causality	Jordan	GDP→EC, EX→EC, financial development→EC
Zambrano-Monserrate et al. (2016)	1971-2011	ARDL, cointegration, Granger causality	Brazil	GDP→CO2, EC→CO2
Matar (2016)	1976-2011	ARDL, Granger causality	Jordan	GDP→EC, FDI→EC, FDI→GDP
Isik et al. (2017)	1970-2014	VECM, Granger causality	Greece	GDP→CO2
Roinioti & Koroneos (2017)	2003-2008, 2008-2013	variance decomposition, decoupling index	Greece	GDP, EC→CO2

Bekhet et al. (2017)	1980-2011	ARDL	Gulf cooperation council countries	EC↔GDP, CO2↔GDP (except UAE)
Aye et al. (2017)	1970-2013	DPTF	31 developing countries	GDP≠CO2
Stjepanovic (2018)	1994-2016	PRFE	30 European countries	EC→GDP
This study	1990-2015	panel cointegration, VECM, Granger causality	old EU and new EU countries	short run: old EU Countries: GDP↔EC, GDP↔CO2, NEXP→GDP, EC↔CO2, FDI→EC, FDI→CO2, CO2↔NEXP, EMP↔FDI, NEXP↔FDI, EC→EMP, CO2→EMP new EU Countries: EC→GDP, CO2→GDP, NEXP→GDP, CO2↔EC, NEXP↔EMP, EC↔EMP, FDI→EC, EMP→GDP, EMP→CO2 long run: bidirectional Granger causality among GDP, EC, CO2, FDI and NEXP

Note: ARDL – Autoregressive distribution lag model, BRIC – Brazil, Russia, India and China, CEE – Central and Eastern European countries, CO2 – Carbon dioxide, DOLS – Dynamic ordinary least squares, DPTF – Dynamic panel threshold framework, EC – Energy consumption, EMP – Employment, FDI – Foreign direct investment, FMOLS – Fully modified ordinary least squares, OLS – Ordinary least squares, PRFE – Panel regression with fixed effects, VECM – Vector error correction model, → unidirectional causality, ↔ bidirectional causality, ≠ no causality.

Table 2: Summary statistics of variables (mean ± standard deviation over 1990-2015)

Country	GDP	Energy cons.	CO2	Employm.	Net export	FDI
Austria	35353±10856	3712±294	7.93±0.53	28.42±6.74	716.3±836.1	-602.3±3373.1
Belgium	33330±10086	5359±292	10.39±0.96	24.75±6.53	835.6±452.6	-639.6±3262.6
Bulgaria	3806.3±2629	2528±197	6.39±0.77	33.70±6.11	-223.1±385.3	-283.8±415.2
Croatia	9738±3577	1809±185	4.52±0.53	29.41±5.88	552.8±5343.2	-454.9±1147.9
Cyprus	20548±8132	2122±175	6.83±0.64	22.64±6.54	-345.5±822.7	8.9±2088.8
Czech Rep.	15365±1222	4189±220	11.54±0.94	39.81±5.68	287.9±467.0	-168.3±869.5
Denmark	43285±13330	3546±262	9.76±1.65	22.83±6.59	2472.6±910.3	487.5±891.5
Estonia	10794±5649	4085±667	12.74±1.24	32.31±5.43	4938.8±15945.3	-612.1±6918.7
Finland	34777±11420	6320±473	10.93±1.14	25.03±5.46	1137.7±1117.3	60.4±1287.9
France	31599±8519	4047±171	5.87±0.41	23.95±6.06	-93.2±557.5	455.1±520.9
Germany	33528±8568	4075±159	10.07±0.68	31.60±7.37	1261.1±1179.8	348.4±581.7
Greece	18189±6905	2399±247	7.93±0.71	21.24±5.72	-1526.4±935.8	-44.3±122.9
Hungary	8721±4248	2528±121	5.56±0.55	31.98±5.70	183.8±484.8	-280.3±248.1
Ireland	36553±16711	3194±318	9.56±1.04	24.91±6.34	5309.9±4075.7	614.7±6296.6
Italy	28870±7300	2847±209	7.45±0.61	30.10±6.05	-6330.5±2406.8	162.2±303.1
Latvia	8531±4673	2042±301	3.57±0.56	25.67±6.01	2268.2±11183.6	-12.5±983.3
Lithuania	8572.8±4679	2709±571	4.38±0.51	27.25±6.07	795.6±5218.9	-208.7±1192
Luxembourg	72432±29223	8268±786	22.11±2.93	18.68±8.22	19715±11926	25435±118560
Malta	13416±5073	1986±135	6.16±0.46	27.09±6.15	-16794±21244	-10276±13972
Netherlands	36795±12269	4654±157	10.61±0.29	18.92±5.98	2934.5±1534.6	1157.6±3011.7
Poland	7422±4473	2518±116	8.47±0.57	30.41±6.22	-98.3±221.4	-175.6±116.1
Portugal	15995±5450	2166±254	5.27±0.68	30.74±6.15	-5617.0±5852.7	-116.0±439.0
Romania	4559±3501	1883±228	4.72±0.74	31.12±6.58	-293.0±342.7	-148.3±168.8
Slovakia	9938±6046	3350±207.6	7.17±0.56	37.73±5.45	-136.9±387.0	313.1±1775.9
Slovenia	17707±5497	3286±318	7.51±0.52	36.70±6.95	240.5±651,1	-72.1±3813.2
Spain	22111±7616	2778±307	6.58±0.89	27.53±6.57	-384.5±720.2	180.3±548.2
Sweden	40190±12246	5496±269	5.72±0.48	22.25±6.39	2167.0±961.2	614.0±1406.2
UK	32192±10042	3530±316	8.83±0.79	23.08±7.25	-620.9±462.9	182.1±1221.7

Table 3: Results of residual cross-sectional dependence tests

Test statistic	15 old EU countries	8 new EU countries
Breusch–Pagan LM	1069.77***	152.69***
Pesaran scaled LM	65.54***	19.24***
Pesaran CD	31.53***	8.78***

Note: *** indicates significance at *P*=0.01.

Table 4: Results of cross-sectional panel unit root test for old EU countries

	CIPS (without trend)			CIPS (with trend)		
Variable	lags=0	lags=1	lags=2	lags=0	lags=1	lags=2
GDP	1.75	-1.98**	-1.13	2.83	-0.80	-0.24
EC	-2.35***	-0.86	0.85	-1.93**	-0.98	1.55
CO2	-0.84	-0.06	0.21	-1.41*	0.99	1.27
FDI	-9.74***	-4.71***	-1.19	-9.12***	-4.29***	-0.65
EMP	0.20	-0.97	0.46	2.38	2.26	4.25
NEXP	1.87	3.49	2.57	4.07	5.29	4.99
Δ GDP	-5.93***	-4.78***	-3.72***	-3.96***	-2.81***	-2.73***
Δ EC	-11.80***	-8.80***	-2.38***	-9.54***	-6.62***	-0.79
Δ CO2	-13.85***	-6.26***	-1.70**	-12.55***	-5.03***	-0.30
Δ FDI	-16.64***	-13.44***	-7.62***	-15.63***	-11.57***	-5.66***
Δ EMP	-9.74***	-4.50***	-1.00	-9.13***	-3.73***	-0.79
Δ NEXP	-8.60***	-1.59*	1.04	-7.68***	-0.20	2.78

Note: * indicates significance at *P*=0.10, ** at *P*=0.05 and *** at *P*=0.01.

Table 5: Results of cross-sectional panel unit root test for new EU countries

	CIPS (without trend)			CIPS (with trend)		
Variable	lags=0	lags=1	lags=2	lags=0	lags=1	lags=2
GDP	-3.80***	-3.81***	-1.85**	-0.24	0.24	0.64
EC	-2.08**	-2.08**	-2.07**	-1.16	0.37	0.37
CO2	-1.61*	-0.50	0.53	-2.86***	-4.66***	0.08
FDI	-7.50***	-5.28***	-3.00***	-7.68***	-6.30***	-2.04**
EMP	-2.26**	-0.31	-0.75	-2.21**	0.35	-0.90
NEXP	1.85	3.17	2.83	0.17	1.41	1.93
Δ GDP	-6.27***	-3.23***	-0.62	-6.16***	-2.63***	-0.04
Δ EC	-10.30***	-3.77***	-2.20**	-10.26***	-3.46***	-1.51*
Δ CO2	-8.59***	-7.70***	-3.88***	-7.94***	-6.01***	-2.95***
Δ FDI	-11.31***	-10.11***	-5.18***	-10.83***	-9.74***	-3.66***
Δ EMP	-10.09***	-3.33***	-4.80***	-9.29***	-2.42***	-3.80***
Δ NEXP	-9.26***	-3.96***	-3.03***	-9.13***	-3.66***	-1.71**

Note: * indicates significance at *P*=0.10, ** at *P*=0.05 and *** at *P*=0.01.

Table 6: Results of combined Fisher-Johansen panel cointegration test

	15 old EU countries		8 new EU countries	
no. of CEs	Fisher stat. (trace)	Fisher stat. (max. eigenvalue)	Fisher stat. (trace)	Fisher stat. (max. eigenvalue)
none	716.1***	645.1***	298.1***	177.4***
at most 1	338.0***	184.5***	151.8***	90.27***
at most 2	178.8***	97.5***	78.31***	41.82***
at most 3	106.0***	72.0***	46.26***	33.28***
at most 4	66.6***	52.6	25.81*	17.58
at most 5	72.2***	72.2***	31.40***	31.40***

Note: * indicates significance at *P*=0.10, *** at *P*=0.01.

Table 7: Panel FMOLS results for old EU countries

	dependent variable					
indep. variable	GDP	EC	CO2	FDI	EMP	NEXP
GDP		0.0077***	-2.32E-05***	-0.3233	-0.0003***	0.2019***
EC	15.42***		0.0024***	14.55*	-0.0011	-3.69***
CO2	-3988.3***	249.4***		-4724.3*	1.17***	1023.5***
FDI	-0.0171	0.0004	-2.33E-07		-1.99E-05**	-0.0064
EMP	-801.90***	-3.01	0.0212**	-805.4**		13.00
NEXP	1.46***	-0.01***	3.63E-05**	0.42	0.0003***	
R^2	0.750	0.983	0.974	0.037	0.473	0.803
Adj. R^2	0.736	0.982	0.972	-0018	0.443	0.793

Note: * indicates significance at *P*=0.10, ** at *P*=0.05 and *** at *P*=0.01.

Table 8: Panel FMOLS results for new EU countries

	dependent variable					
indep. variable	GDP	EC	CO2	FDI	EMP	NEXP
GDP		0.0046*	-4.20E-06	-0.03*	-0.0003***	-0.0087
EC	6.29		0.0021***	1.40**	-0.0047	-1.56
CO2	-532.4	180.1***		50.8	2.72***	-277.9
FDI	-0.26	-0.0001	2.44E-05		-0.0007**	5.12E-05
EMP	-279.7**	-5.57**	0.02**	-43.3**		-7.99
NEXP	-0.09	-0.01	-2.84E-05	0.08	-0.0002	
R^2	0.987	0.965	0.951	0.077	0.523	0.062
Adj. R^2	0.985	0.963	0.947	0.014	0.490	-0.001

Note: * indicates significance at *P*=0.10, ** at *P*=0.05 and *** at *P*=0.01.

Table 9: Results of panel Granger causality test for old EU countries

	independent variables						
dependent variable	Δ GDP	Δ EC	Δ CO2	Δ FDI	Δ EMP	Δ NEXP	ECT
Δ GDP		25.35***	17.06***	21.99***	1.52	5.82***	-0.16***
Δ EC	2.49*		148.08***	7.66***	1.25	0.78	-0.36***
Δ CO2	5.55***	5.11***		19.98***	0.17	4.78***	-0.38***
Δ FDI	0.49	0.48	2.32		3.30**	8.52***	-1.28***
Δ EMP	0.45	125.90***	224.79***	17.87***		1.35	-0.35
Δ NEXP	1.63	1.70	4.18**	4.66**	1.25		-0.23***

Note: * indicates significance at *P*=0.10, ** at *P*=0.05 and *** at *P*=0.01.

Table 10: Results of panel Granger causality test for new EU countries

	independent variables						
dependent variable	Δ GDP	Δ EC	Δ CO2	Δ FDI	Δ EMP	Δ NEXP	ECT
Δ GDP		12.79***	14.31***	0.69	2.45*	0.07	-0.23***
Δ EC	0.06		3.83**	3.24**	16.52***	1.87	-0.49***
Δ CO2	0.40	15.66***		1.36	51.72***	1.02	-0.27***
Δ FDI	1.92	0.57	0.08		2.87	2.30	-0.10*
Δ EMP	0.68	4.04**	0.82	0.34		8.78***	0.87
Δ NEXP	0.12	1.18	0.23	0.12	2.36*		-0.12**

Note: * indicates significance at *P*=0.10, ** at *P*=0.05 and *** at *P*=0.01.

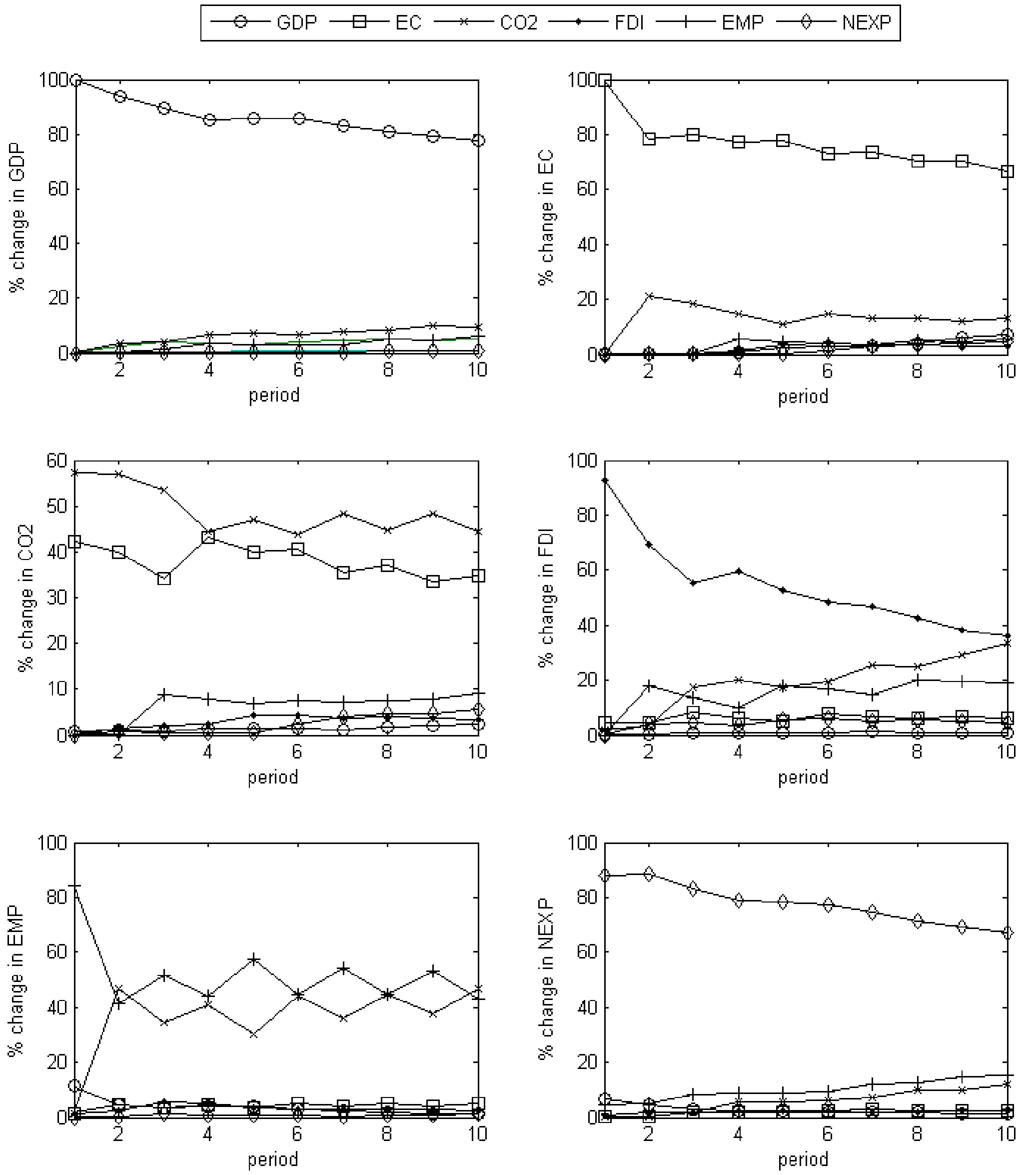
Figure legends:

Fig. 1: Variance decomposition of outputs – old EU countries

Fig. 2: Variance decomposition of outputs – new EU countries

Fig. 3: Impulse response functions of GDP for old EU countries

Fig. 4: Impulse response functions of GDP for new EU countries



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EMP
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% change in EC
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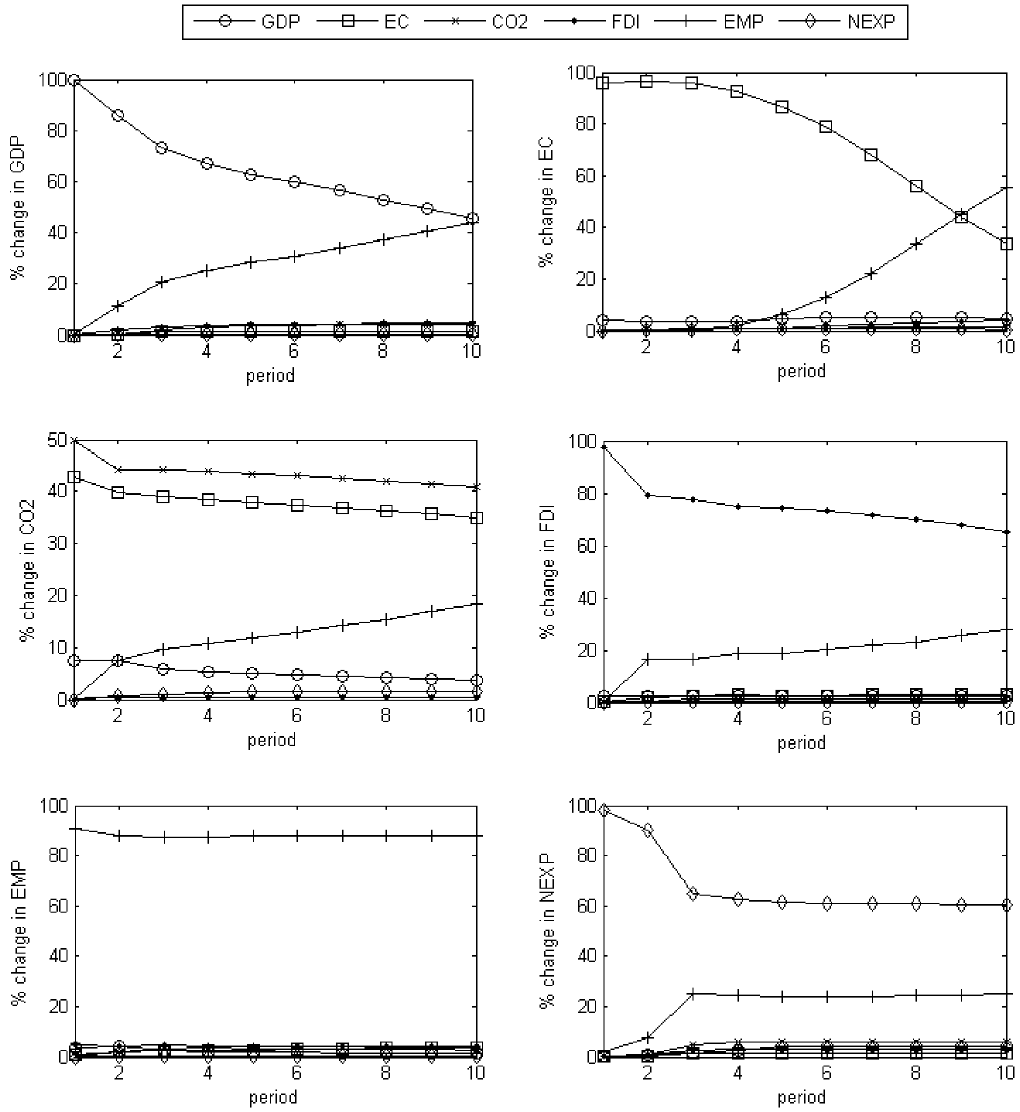
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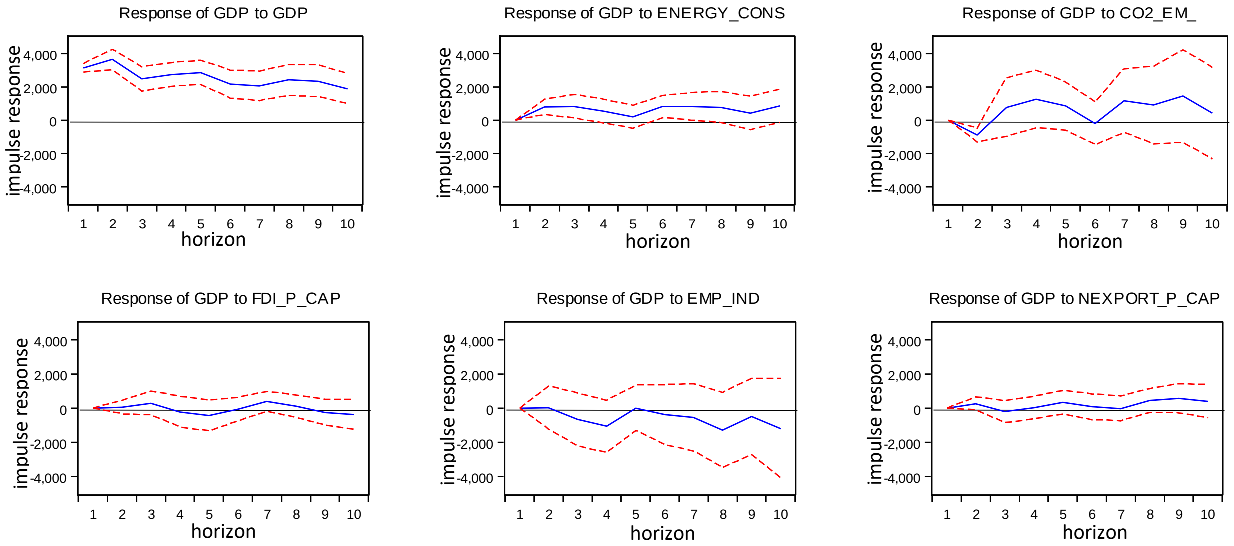
Response of GDP to GDP
Response of GDP to ENERGY_CONS
Response of GDP to CO2_EM_
Response of GDP to FDI_P_CAP
Response of GDP to EMP_IND
Response of GDP to NEXPORT_P_CAP
impulse response
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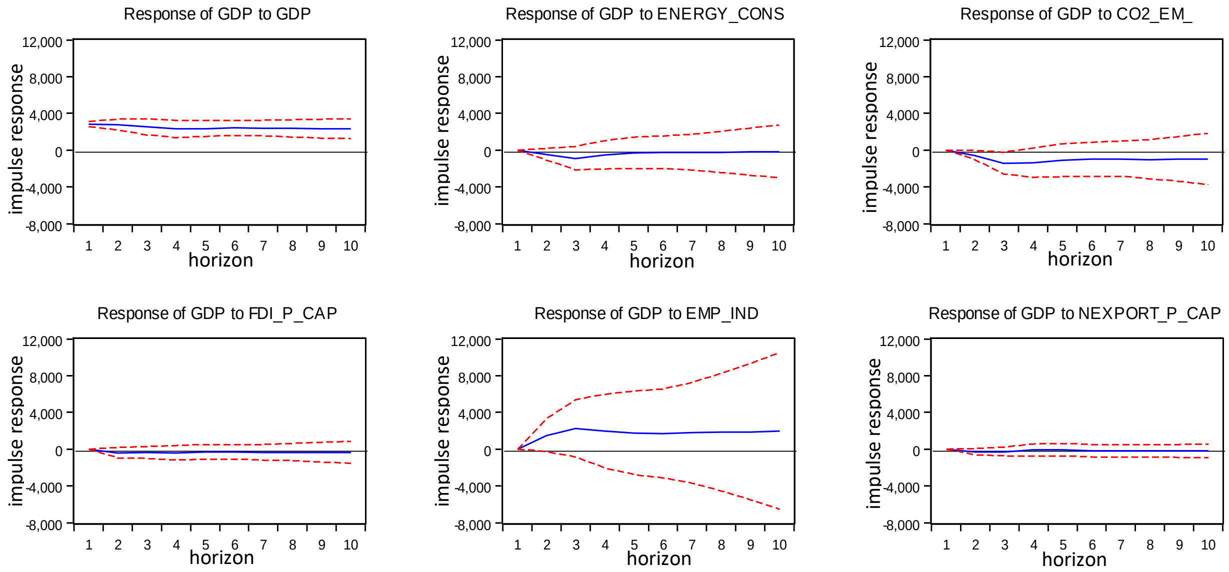
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