Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Does the electricity consumption and economic growth nexus alter during COVID-19 pandemic? Evidence from European countries

Hünkar Güler a, Özkan Haykırb, Selçuk Öz c

a Faculty of Economics and Administrative Science, The Department of Public Finance, Nigde Omer Halisdemir University, Nigde 51240, Turkey
b The Republic of Turkey Ministry of Transportation and Infrastructure, Ankara 06530, Turkey
c Faculty of Economics and Administrative Science, The Department of Finance and Banking, Nigde Omer Halisdemir University, Nigde 51240, Turkey

ARTICLE INFO

Jel Classifications:
C13
O47
O52
Q43

Keywords:
COVID-19 pandemic
Economic growth
Electricity consumption
Panel causality test

ABSTRACT

This paper examines the impact of the COVID-19 pandemic on the electricity consumption and economic growth nexus using 30 European countries’ quarterly data between 2015Q1 and 2021Q3. We employ the panel unit root, panel causality, and dynamic panel estimation tests and find that there is bi-directional causality between electricity consumption and economic growth. The findings of this study provide new insights into understanding the electricity consumption and economic growth nexus by suggesting that an increase in electricity consumption during the COVID-19 pandemic decreases economic growth. We also investigate the strict confinement period of the COVID-19 pandemic as a robustness test. The results of robustness analysis reveal that there is an even stronger negative impact of electricity consumption on economic growth due to the pandemic influenza mitigation strategies such as lockdowns and business’ shutdowns that cause people to intensely consume residential electricity.

1. Introduction

The oil shock of 1973 resulted from the embargo of the Yom Kippur War kept energy prices fluctuating and input cost increasing. Besides, an upsurge in energy demand due to the production for the growing population, urbanization, and high standard of living (rising per capita income) and environmental considerations such as climate change and global warming are key issues concerning EU countries. Because of these reasons, the issue of energy security has gained importance for European countries and researchers started to investigate the nexus between electricity consumption and economic growth. However, the impacts of natural disasters such as earthquakes, hurricanes, and pandemics on this nexus have not been sufficiently examined yet.

In this paper, we investigate the nexus between economic growth and electricity consumption including the COVID-19 pandemic period by employing panel unit root, panel causality, and dynamic panel estimation methods. Our sample includes 30 European countries and the sample period covers between 2015Q1 and 2021Q3. The empirical findings contribute to existing research filling the gaps in energy economics literature by scrutinizing the effect of the COVID-19 pandemic on the electricity consumption-economic growth nexus. The first contribution shows that there is bi-directional causality between electricity consumption and economic growth during our sample period. The second is that there is no significant effect of economic growth on electricity consumption; however, there is a significant and negative effect of electricity consumption on economic growth during the COVID-19 pandemic. Lastly, there is an even stronger negative impact of electricity consumption on economic growth during the strict confinement period.

Pandemic is not just an important health issue killing millions of people rather more than wars, it also hurts economic stability that is impacted by demand and supply reductions in the short run and re-shapes economic structure in the long run. The pandemic the world is currently facing has been called COVID-19 (SARS-CoV-2), and the first coronavirus case was recorded in Wuhan city of Hubei province of China. The first death outside of China due to COVID-19 was seen in Italy where the pandemic affected most outside of Asia on February 23rd, 2020, and proclaimed that Europe started to become the center of the...
pandemic of March 13th, 2020. Official records say that over 5.5 million people have already died of this disease around the world, and it is presently milder than the Spanish flu (WHO, 2021). On the one hand, governments attempt to curb the spread pace of pandemic, on the other hand, they struggle to provide economic stability in these unprecedented circumstances.

Governments employ some precautionary measures such as part-time employment, home confinement (quarantine), social distancing, travel restrictions and bans, closure of borders, schools, and crowded places as well. However, these pandemic influenza mitigation strategies reveal crucial economic repercussions and tangible changes whereas decreasing the negative effects of pandemics. For instance, Baker et al. (2020) research the economic effects of the COVID-19 pandemic for the USA and they show sharp drops in demand for restaurants, retail, and travels. Barrot et al. (2020) suggest that six-week social distancing decreases the gross domestic product (GDP) by 5.6% in France. Moreover, Bahmanyar et al. (2020) reveal that countries which employed strict lockdown measures have experienced a sharp reduction in daily electricity consumption compared to the countries carrying out lax measures. The newest and closest paper is written by Soavia et al. (2021) that analyzes the impact of the COVID-19 pandemic on the electricity consumption-economic growth nexus for Romania by using time series analysis. They distinguish electricity consumption data into domestic and non-household electricity consumption and then examine their relationships with economic growth. The paper unfolds the COVID-19 pandemic has a significant negative impact on electricity consumption and economic growth nexus. Moreover, results indicate that there is bi-directional causality between domestic electricity consumption and economic growth, and also there is uni-directional causality running from non-household electricity consumption to economic growth.

The relationship between electricity consumption and economic growth can be examined under four different hypotheses. These are (i) growth hypothesis, (ii) conservation hypothesis, (iii) feedback hypothesis, and (iv) neutrality hypothesis. The growth hypothesis takes effect if uni-directional causality runs from electricity consumption to economic growth. The conservation hypothesis assumes that causality runs from economic growth to electricity consumption. The feedback hypothesis indicates bi-directional causality between electricity consumption and economic growth. The neutrality hypothesis suggests no link between electricity consumption and economic growth. The results for the specific countries show that 31.15% supports the neutrality hypothesis, 22.95% the growth hypothesis, 27.87% the conservation hypothesis, 22.95% the growth hypothesis, and 18.03% the feedback hypothesis (Payne, 2010).

The rest of this paper is organized as follows. Section 2 summarizes the prior literature. Section 3 explains the data and methodology. Section 4 shows the empirical results and finally, Section 5 concludes the paper.

2. Brief overview of literature

Economic growth theories have not sufficiently focused on the effect of natural resources on economic growth. Mainstream economists take into account the primary factors of production such as capital, labor, and land, but they never consider fossil fuels and materials as a factor of production. It is difficult to correctly estimate the nexus between energy, and economic growth without knowing the role of energy in the production process. Because of this reason and especially along with the impact of the oil crisis in the 1970s, Kraft and Kraft (1978) first scrutinized the causal relationship between energy consumption and economic growth and they found uni-directional relation running from the gross national product (GNP) to gross energy consumption for the USA. After this pioneering paper, the nexus was re-examined by Akarca and Long (1980), Yu and Hwang (1984), and Yu and Choi (1985), respectively. The nexus between energy consumption and economic growth has long-standing literature, but studies do not agree with each other because of sample selection issues (Oztürk, 2010).

Brief literature on energy consumption-economic growth nexus is shown in Table 1. Menegaki (2011) benefits from the multivariate approach and investigates the causality between renewable energy consumption and GDP across Europe between the years of 1997 – 2007 by employing a panel causality test. This paper presents evidence of the neutrality hypothesis. Belke et al. (2011) examine the relationship between energy consumption and economic growth for 25 OECD countries in the period between 1981 and 2007 by using a panel Granger causality test. Authors suggest a bi-directional causality and discover that energy consumption is price inelastic. Kasman and Duman (2015) use the multivariate approach and analyze the causal relationship between energy consumption and economic growth for the new EU members and candidate countries between the years of 1992–2010 by employing panel causality tests. Results indicate uni-directional causality running from economic growth to energy consumption, that is, conservation hypothesis, and provide evidence supporting the Environmental Kuznet Curve (EKC) hypothesis. Last but not least, Magazzino (2015) reaches the feedback hypothesis for Italy.

After the energy consumption-economic growth nexus in literature, the relationship between electricity consumption and economic growth has begun to be studied. Brief literature on electricity consumption-economic growth nexus is shown in Table 2. Narayan and Prasad (2008) inquire about any causality between electricity consumption and economic growth for 30 OECD countries over the period from 1960 to 2002 by using the bootstrap causality approach. They find the causality running from real GDP to electricity consumption for Finland, Hungary, and the Netherlands. Accordingly, electricity conservation policies never negatively affect real GDP in these countries. Moreover, the growth hypothesis is valid for Australia, Italy, Slovak Republic, Czechia, and Portugal. This is to say, electricity conservation policies seriously impact real GDP in these countries. They also reveal bi-directional causality for Iceland, Korea, and the UK. Finally, there is no link between economic growth and electricity consumption for the rest. Kim (2015) and Karanfil and Li (2015) study large country groups in the same year and reach bi-directional causality. Azam et al. (2021) seek the impact of renewable electricity consumption on economic growth and CO2 emissions for the newly industrialized countries (NICs) over the period from 1994 to 2015 by using panel data analysis. Findings signify that renewable electricity consumption has a positive but statistically insignificant effect on economic growth, yet it alleviates CO2 emissions in the long run (Papiez et al., 2019).

Economists have been intensely studying the effects of the COVID-19 pandemic on electricity consumption, and economic growth separately since the first quarter of 2020. There has been a significant reduction in global energy demand because of containment policies around the world since the first quarter of 2020 whereas EU countries have increased the share of renewable energy in the electricity generation mix (Hoang et al., 2021). Santiago et al. (2021) examine the effects of confinement measures on electricity consumption in Spain from March 14 to April 30, 2020. They find a reduction in electricity consumption of 13.5% in regard to consumption during the same period in the previous five years and the share of renewable energy has been increased. Cicala (2020) evaluates the impact of pandemic measures on electricity consumption in Europe. Electricity consumption in Europe has roughly decreased 10% since the measures started to implement. The highest reduction in electricity consumption is seen in Italy, almost 25%, and in Spain 15%. Pezzi and Fanghella (2020) study the effects of measures on GDP and electricity consumption in Italy. They designate that the 3-week-severe lockdown measures in March and April 2020 create enormous reductions in GDP and electricity consumption. They also estimate that confinement measures in Italy decreased GDP by almost 5.1% during the first quarter of 2020 and a 30% reduction during this 3-week lockdown. Moreover, they find a 20% reduction in electricity consumption in these 3 weeks.
France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Turkey, and the United Kingdom. We download the quarterly GDP at market prices (in millions) and monthly total electricity consumption (gigawatt-hour) from Eurostat.\(^1\) The sample period spans between 2015Q1 and 2021Q3. We convert monthly total electricity consumption for each country to quarterly data by adding up the three months of electricity consumption.

This paper aims to show that whether economic growth and electricity consumption nexus has changed during the COVID-19 pandemic period. To reach our aim, first, we examine the stationary of variables by employing various panel unit root tests. Second, we investigate the short-run relationship between economic growth and electricity consumption using panel-causality analysis. Finally, we adopt a dynamic panel estimation methodology to test the effect of the COVID-19 pandemic on the economic growth and electricity consumption nexus. As a robustness analysis, we employ dynamic panel method using the period between 2015Q1–2020Q3, which we name as strict confinement period in order to understand the initial impact of COVID-19 pandemic.

### 3. Data and methodology

The sample includes 30 European countries, namely Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Turkey, and the United Kingdom. We download the quarterly GDP at market prices (in millions) and monthly total electricity consumption (gigawatt-hour) from Eurostat.\(^1\) The sample includes 30 European countries, namely Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Turkey, and the United Kingdom. We download the quarterly GDP at market prices (in millions) and monthly total electricity consumption (gigawatt-hour) from Eurostat.\(^1\) The sample period spans between 2015Q1 and 2021Q3. We convert monthly total electricity consumption for each country to quarterly data by adding up the three months of electricity consumption.

#### 3.1. Cross-sectional dependency test

In panel studies, numerous panel-unit root tests can be employed, but before deciding which unit-root test to apply, the cross-sectional dependency of the variables should be checked since it leads to employing certain unit root tests. If there is a cross-sectional dependency, the second-generation panel-unit tests should be employed. There are several cross-sectional dependency tests in the literature such as Breusch-Pagan (1980) LM test, the Pesaran (2004) CD test, and Baltagi et al. (2012) LM test. Unlike the others, Pesaran’s (2004) CD test is well-performed in the small sample where N > T; hence, we employ the Pesaran CD test which is calculated based on the pairwise correlation coefficient from the residuals of the ADF regressions. It is constructed as follows:

\[
CD = \sqrt{\frac{2T}{N(N - 1)} \left( \sum_{i=2}^{N} \sum_{j=1}^{N} r_{ij} \right)}
\]  \(1\)

The null and alternative hypothesis of Pesaran (2004) CD test can be written as follows:

\[
H_0 : \quad \rho_{ij} = 0
\]

\(2\)

\[
H_A : \quad \rho_{ij} \neq 0
\]

\(3\)

Table 3 presents the results of the Pesaran cross-sectional dependency test using the logarithm of GDP and electricity consumption. Since the p-values are less than 0.01 for both variables, there exists cross-sectional dependency. The average absolute correlation of log (gdp) between countries is 0.688 and for log(electricity) is 0.594. Since the sample covers European countries, this is anticipated. Due to cross-

---

\(1\) 2020Q4–2021Q3 GDP data of the United Kingdom is downloaded from Office for National Statistics [https://www.ons.gov.uk/](https://www.ons.gov.uk/) and electricity consumption of the United Kingdom is retrieved from Statista [https://www.statista.com/statistics/322996/monthly-electricity-consumption-from-all-electricity-suppliers-in-the-united-kingdom-uk/).
Δ can be formulated as follows: 

\[ \Delta Y_t = \alpha_{it} + \rho_t Y_{t-1} + d_t \bar{T}_t + d_j T_j + \varepsilon_{it} \]  

(4) 

The null hypothesis is \( \rho_t = 0 \) and the alternative is not. CIPS can be calculated as follows:

\[ t(N, T) = \frac{\Delta Y \tilde{M}_{Y-1}}{\tilde{b} (Y_{-1} \tilde{M}_Y)_{-1}^{1/2}} \]  

(5) 

The null hypothesis is rejected in both variables. Thus, we conclude that variables are stationary in level. Because of the results in the unit root tests, we decide to analyze the short-term relationship between electricity consumption and economic growth and using the panel causality test. In order to determine which causality test should be employed, the homogeneity of the parameters should be checked.

### 3.3. Homogeneity tests

It is vital to detect whether the parameters in the model are homogeneous or heterogeneous when conducting a causality test in panel data. In other words, if the parameters are homogeneous, the preferred causality test is the panel Granger causality test. If the parameters of the model show heterogeneous characteristics and the slope parameters vary from unit to unit, then Dumitrescu and Hurlin (2012) causality test should be applied. Therefore, before proceeding to the causality test, the homogeneity of the parameters should be tested. Swamy (1970) develops a model to examine whether the parameters are homogeneous or heterogeneous. The Swamy S test statistics can be calculated as follows:

\[ \tilde{X}_{(N-1)} = \sum_{i=1}^{N} \left( \hat{\beta}_i - \bar{\beta} \right)^2 \]  

(6)

**Table 2**

Brief literature on electricity consumption-economic growth nexus.

| Authors | Period | Sample | Methodology | Results |
|---------|--------|--------|-------------|---------|
| Soava et al. (2021) | 2007–2020 | Romania | Time Series Analysis | ELC ⇔ EG |
| Azam et al. (2021) | 1994–2015 | NICs | Panel Data Analysis | RELC | EG |
| Karanfil and Li (2015) | 1980–2010 | 160 countries | Panel Data Analysis | ELC ⇔ EG (All countries) |
| Kim (2015) | 1971–2009 | 109 countries | Multiple-Component Model | ELC ⇔ EG (East Asia and Pacifics, Middle East, North Africa) |
| Cowan et al. (2014) | 1990–2010 | BRICS Countries | Panel Causality Test | ELC | EG (North America) |
| Oztürk and Acaravcı (2011) | 1971–2006 | 11 MENA Countries | ARDL Bound Test | ELC ⇔ EG (Brazil, India, and China) |
| Narayan and Prasad (2008) | 1960–2002 | 30 OECD Countries | Bootstrap Causality Approach | ELC ⇔ EG (Iran, Morocco, and Syria) |
| Narayan et al. (2008) | 1960–2002 | G7 Countries | SVAR | ELC ⇔ EG (Israel and Oman) |
| Squalli (2007) | 1980–2003 | 11 OPEC Countries | Bounds Test and Non-Causality Test of Toda-Yamamoto | ELC ⇔ EG (Egypt and Saudi Arabia) |
| Soyaş and Sari (2007) | 1968–2002 | Turkey | Johansen Co-integration Test | ELC ⇔ EG (Oman) |
| Narayan and Smyth (2005) | 1966–1999 | Australia | Multivariate Granger Causality Test | ELC ⇔ EG (Austria, Italy, Slovak Republic, Czechia, and Portugal) |
| Altinay and Karagöl (2005) | 1950–2000 | Turkey | Granger Causality Test and Dolado-Lütkepohl Test | ELC ⇔ EG (Finland, Hungary, Netherlands) |
| Jumbe (2004) | 1970–1999 | Malawi | VECM | ELC ⇔ EG (Iceland, Korea, UK) |
| Akgül and Ozcakmak (2009) | 1960–2006 | 11 MENA Countries | ARDL Bound Test | ELC ⇔ EG (Except for the USA) |
| Alatise et al. (2008) | 1962–2001 | 11 MENA Countries | ARDL Bound Test | ELC ⇔ EG (Except for Italy) |
| Oztürk and Acaravcı (2011) | 1971–2006 | 11 MENA Countries | ARDL Bound Test | ELC ⇔ EG (Algeria, Iraq, Libya) |
| Narayan and Prasad (2008) | 1960–2002 | 30 OECD Countries | Bootstrap Causality Approach | ELC ⇔ EG (Iran, Qatar) |
| Narayan et al. (2008) | 1960–2002 | G7 Countries | SVAR | ELC ⇔ EG (Nigeria, Indonesia, Venezuela) |
| Squalli (2007) | 1980–2003 | 11 OPEC Countries | Bounds Test and Non-Causality Test of Toda-Yamamoto | ELC ⇔ EG (Kuwait, Saudi Arabia, and the UAE) |
| Soyaş and Sari (2007) | 1968–2002 | Turkey | Johansen Co-integration Test | ELC ⇔ EG (Iran, Qatar) |
| Narayan and Smyth (2005) | 1966–1999 | Australia | Multivariate Granger Causality Test | ELC ⇔ EG (Nigeria, Indonesia, Venezuela) |
| Altinay and Karagöl (2005) | 1950–2000 | Turkey | Granger Causality Test and Dolado-Lütkepohl Test | ELC ⇔ EG (Except for Italy) |
| Jumbe (2004) | 1970–1999 | Malawi | VECM | ELC ⇔ EG (Except for Italy) |

**Note:** ELC: Renewable EL Consumption, ELC: Electricity consumption, EG: Economic growth, ± : Adverse nexus, | : Neutrality hypothesis.

---

### 3.2. Panel unit root test

Due to the existence of the cross-sectional dependency, we employ the panel unit root tests that consider either eliminate the effect of dependency or take into account the existence of it. In this respect, we apply two second-generation panel unit root tests to produce reliable estimation, namely Pesaran’s (2007) cross-sectional augmented Dickey-Fuller (CADF) and Im et al.’s (2003) cross-sectional augmented tests (CIPS). CADF regression without autocorrelation and its t-statistic can be formulated as follows:

\[ \Delta Y_t = \alpha_{it} + \rho_t Y_{t-1} + d_t \bar{T}_t + d_j T_j + \varepsilon_{it} \]  

(6)
where $\hat{\beta}_i$ is the OLS coefficients that estimated from cross-sectional regressions and $\bar{\bar{P}}$ is the coefficient from pooled weighted estimation. Even though Swamy S test is a widely used method to capture the homogeneity in the parameters, it generally produces better results when the number of periods exceeds the number of units ($T > N$). Due to this limitation, we also apply the Pesaran and Yamagata (2008) test where they modify the Swamy S test to be used when the number of units is higher than the number of periods ($N > T$).

Table 5 presents two homogeneity tests, Swamy S and Pesaran and Yamagata. For both tests, we estimate a regression where the log(gdp) and log(electricity) are dependent variables, and their own lagged values and the other variables are used as independent variables. The results indicate that the null hypothesis is rejected and we adopt Dumitrescu and Hurlin causality test instead of the Granger causality test as further analysis.

4. Empirical results

To understand the causal link between variables, while the variables are stationary in levels and there is heterogeneity in parameters, one should employ the Dumitrescu and Hurlin (2012) panel causality test. Dumitrescu and Hurlin (2012) test provides desirable results even if the number of units is smaller than the number of periods. The mathematical representation of Dumitrescu and Hurlin (2012) panel causality test and its null and alternative hypotheses are as follows:

\[
\begin{align*}
\text{Log(GDP)}_i &= \alpha_0 + \beta_0 + \sum_{k=1}^{K} \beta_{0k} Y_{it-k} + \sum_{k=1}^{K} \beta_{1k} X_{it-k} + \varepsilon_{it} \quad (7) \\
\text{H}_0 : \beta_i = 0 & \quad i = 1, \ldots, N \quad (8) \\
\text{H}_1 : \beta_i \neq 0 & \quad i = 1, \ldots, N_1 \quad \text{or} \quad \beta_i = 0 \quad i = N_1 + 1, N_2 + 2, \ldots, N \quad (9) \\
\end{align*}
\]

The test statistic of Dumitrescu and Hurlin (2012) panel causality test is calculated using Wald test statistics.

\[
W_{it,T} = \frac{1}{N} \sum_{i=1}^{N} W_{it} \quad (11)
\]

Table 6 shows the Dumitrescu and Hurlin non-causality test results. First, we analyze the causality from the log(gdp) to log(electricity), and secondly, we examine the causality from the log(electricity) to log(gdp). The Wald test and bootstrap p-values have been shown to determine the significance levels. The results demonstrate that there is a significant bi-directional causality between electricity consumption and economic growth, and this finding supports the feedback hypothesis as in prior literature (i.e. Soava et al., 2021; Karanfil and Li, 2015; Kim, 2015).

The purpose of this paper is to examine the effect of the COVID-19 pandemic on the economic growth and electricity consumption nexus. To reach this aim, we generate “covid” as a dummy variable that gets one if the sample period is between 2020Q1 and 2021Q3 and zero otherwise. We also construct an interaction term for GDP and electricity consumption with covid to determine the impact of the pandemic on the economic growth and electricity consumption nexus. It is possible to examine panel analysis methods as static or dynamic models. In order to choose the dynamic model over the static model, the dataset must have a small number of periods and a large number of unit dimensions ($N > T$) (Roodman, 2009). Thus, we employ the dynamic panel analysis and estimate the following system GMM equations:

\[
\begin{align*}
\text{Log(GDP)}_i &= \alpha_0 + \beta_0 + \sum_{k=1}^{K} \beta_{0k} Y_{it-k} + \sum_{k=1}^{K} \beta_{1k} X_{it-k} + \varepsilon_{it} \quad \text{or} \quad \text{Log(Electricity)}_i = \alpha_0 + \beta_0 L1(\text{Log(GDP)}_i) + \beta_1 (\text{Log(Electricity)}_i) + \beta_2 \text{Covid}_i + \varepsilon_{it} \quad (12) \\
\text{Log(Electricity)}_i &= \alpha_0 + \beta_0 + \sum_{k=1}^{K} \beta_{0k} Y_{it-k} + \sum_{k=1}^{K} \beta_{1k} X_{it-k} + \varepsilon_{it} \quad \text{or} \quad \text{Log(GDP)}_i = \alpha_0 + \beta_0 L1(\text{Log(Electricity)}_i) + \beta_1 (\text{Log(GDP)}_i) + \beta_2 \text{Covid}_i + \varepsilon_{it} \quad (13)
\end{align*}
\]

Table 7 reports the dynamic panel estimation results. In the first column, the dependent variable is log(gdp) and the independent variables are the lagged values of GDP, electricity consumption along with covid and interaction term (covid*log (electricity)). The results suggest that there is a positive effect of electricity consumption on economic growth during full period. In other words, higher electricity consumption generates higher GDP in the next quarter. One percent increase in electricity consumption will increase GDP by 0.077%. On the contrary, the interaction term is negative and statistically significant. One percent increase in electricity consumption during the COVID-19 period will lower the GDP by 0.013%.

In the second column, the dependent variable is log(electricity) and the independent variables are the lagged values of GDP and electricity consumption along with covid and interaction term (covid*log (electricity)). Similarly, the positive and significant relationship between lagged GDP and electricity consumption can be seen in the results. Unlike the first column, the interaction term is statistically insignificant. This suggests that there is no significant impact of the GDP on electricity consumption during COVID-19 pandemic.

Governments impose the strict confinements such as lockdowns and business’ shutdowns due to high uncertainty at the beginning of the COVID-19 pandemic. To understand the initial impact of COVID-19 on the electricity consumption and economic growth nexus, we generate “covid” as a dummy variable that gets one if the sample period is between 2020Q1 and 2020Q3 and zero otherwise, and apply Eqs. (12) and (13). During the strict confinement period, the robustness test results indicate that the negative impact of electricity consumption on economic growth is even stronger. One percent increase in electricity consumption during the strict confinement period will lower the GDP by 0.034%. Overall, there is bi-directional relation between electricity consumption and economic growth which supports feedback hypothesis.

Table 5
Homogeneity test.

| Dependent Variable | Swamy S Test | Pesaran and Yamagata |
|--------------------|--------------|----------------------|
| Log (GDP)          | 321.69***    | 6.537***             |
| Log (Electricity)  | 848.40***    | 2.907**              |

Notes: P-values are in the parenthesis. *, **, *** show the statistical significance at the 10, 5, and 1% level, respectively.

Table 6
Dumitrescu-Hurlin non-causality test.

|                           | W- Bar | Z-Bar | P- Value | Bootstrap P- Value |
|---------------------------|--------|-------|----------|--------------------|
| Log (GDP) to Log (Electricity) | 32.29  | 5.73  | 0.000    | 0.000              |
| Log (Electricity) to Log (GDP)    | 14.68  | 13.14 | 0.000    | 0.008              |
as in Table (6) but the relation has changed due to pandemic. The electricity consumption has negative impact on economic growth during COVID-19 period. Since people stay in their houses and consume residential electricity during strict confinement period, the negative effect of electricity consumption on economic growth is even stronger. The results are consistent with Barrot et al. (2020), Bahmanyar et al. (2020), and Soava et al. (2021).

The post-estimation results of Wald and AR(2) tests are in the acceptable range and suggest that the regression is well-constructed and there is no serial correlation in the second lagged values. Hansen test suggests that there is no over-identification in regressions since the coefficients are insignificant in both cases.

5. Conclusion

This paper attempts to investigate the impact of the COVID-19 pandemic on the economic growth and electricity consumption nexus using data from 30 European countries between 2015Q1 and 2021Q3 by employing several panel data methodologies such as panel unit root, panel causality tests, and dynamic panel estimation. The contribution of the paper is three folds. First, our paper contributes to the vast literature on the electricity consumption and economic growth nexus by analyzing the causal relationship between economic growth and electricity consumption including the COVID-19 pandemic period. Secondly, we investigate the impact of the COVID-19 pandemic on the economic growth and electricity consumption nexus by including a dummy variable and employ dynamic panel estimation. Lastly, we use strict confinement period and re-examine the effect of the COVID-19 pandemic on the economic growth and electricity consumption nexus. The first finding of this paper demonstrates that there is a significant bi-directional causality between the electricity consumption and economic growth. The second finding indicates the effect of electricity consumption on economic growth is negative and statistically significant during the COVID-19 pandemic. The result also shows that electricity consumption increases the next period GDP during full period. Thirdly, finding supports the negative impact of electricity consumption on economic growth during strict confinement period.

Overall, results support the feedback hypothesis that indicates bi-directional causality between electricity consumption and economic growth in our sample period. On the other hand, the effect of electricity consumption on economic growth becomes negative during the COVID-19 period as a consequence of the pandemic influenza mitigation strategies such as lockdowns and business’ shutdowns that cause people to intensely consume residential electricity. Therefore, governments should (i) strengthen the positive effect of electricity consumption on economic growth during pandemics, (ii) apply rigorous and coherent confinement measures so as not to completely suspend the economic activities, and (iii) support international collaborations in order to prevent the global outbreak in order to maintain the positive effect of electricity consumption on economic growth.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Acaravcı, A., 2010. Structural breaks, electricity consumption and economic growth: evidence from Turkey. Romanian J. Econ. For. 13 (2), 145–154. [http://www.ipe.ro/nrj/nrj2,10/nrj2_10_8.pdf].
Akarcı, A.T., Long, T.V., 1980. Relationship between energy and GNP: a reexamination. J. Energy Finance Dev. 5 (2), 326–331. [https://www.researchgate.net/publication/256379528_Relationship_between_energy_and_GNP_A_reexamination].
Altinyay, G., Karagol, E., 2005. Electricity consumption and economic growth: evidence for Turkey. Energy Econ. 27 (6), 849–856. https://doi.org/10.1016/j.eneco.2005.07.002.
Aparigis, N., Payne, J.E., 2010a. The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states. Energy Pol. 38 (1), 650-655. https://doi.org/10.1016/j.enpol.2009.08.029.
Aparigis, N., Payne, J.E., 2010b. Renewable energy consumption and growth in Eurasia. Energy Econ. 32 (6), 1392–1397. https://doi.org/10.1016/j.eneco.2010.06.001.
Azaiz, A., Raffo, M., Shafique, M., Ateeq, M., Yuan, J., 2021. Investigating the impact of renewable electricity consumption on sustainable economic development: a panel ARDL approach. Int. J. Green Energy 18, 1–9. https://doi.org/10.1080/15439075.2021.1897825.
Bahmanyar, A., Etezabi, A., Ernst, D., 2020. The impact of different COVID-19 containment measures on electricity consumption in Europe. Energy Res. Social Sci. 68, 1–4. https://doi.org/10.1016/j.erss.2020.101683.
Baker, S.R., Farrokhnia, R.A., Meyer, S., Pagel, M., Yannelis, C., 2020. How does household spending respond to an epidemic? consumption during the 2020 COVID.
Cowan, W.N., Chang, T., Inglesi-Lotz, R., Gupta, R., 2014. The nexus of electricity consumption and economic growth: new insights into the cointegration relationship. Energy Econ. 33 (5), 517–527. https://doi.org/10.1016/j.eneco.2014.07.012.

Karanfil, F., Li, Y., 2015. Electricity consumption and economic growth: exploring panel-cointegration across EU countries using a bootstrapped causality test. Energy Policy 87 (3), 309–322. https://doi.org/10.1016/j.enpol.2015.02.015.

Yu, E.S.H., Hwang, B.K., 1984. On the relationship between energy and GNP: further evidence from multivariate Granger causality tests. Energy Policy 33 (9), 2722–2729. https://doi.org/10.1016/S0304-4076(03)00092-7.

Soyta, U., Sars, R., 2003. Energy consumption and GDP causality relationship in G-7 countries and emerging markets. Energy Econ. 25 (1), 33–37. https://doi.org/10.1016/S0140-9883(02)00009-9.

Soyta, U., Song, B., 2007. The relationship between energy and production: evidence from Turkish manufacturing industry. Energy Econ. 29 (6), 1151–1165. https://doi.org/10.1016/j.eneco.2006.05.019.

Squalli, J., 2007. Electricity consumption and economic growth: bounds and causality analyses of OPEC members. Energy Econ. 29 (6), 1192–1205. https://doi.org/10.1016/j.eneco.2006.10.001.

Swamy, P., 1970. Efficient Inference in a Random Coefficient Regression Model. Econometrica 38 (2), 311–322. https://doi.org/10.2307/1913012.

Tani, S.Z., 2010. Energy consumption and economic growth: a causality analysis for Greece. Energy Econ. 32 (3), 582–590. https://doi.org/10.1016/j.eneco.2009.09.007.

WHO, 2021. WHO Coronavirus Disease (COVID-19) Dashboard. https://covid19.who.int/ (accessed 7 January 2022).

Yıldırım, E., Aslan, I., 2012. Energy consumption and economic growth nexus for 17 highly developed OECD countries: further evidence based on bootstrap-corrected causality tests. Energy Policy 51 (December), 985–993. https://doi.org/10.1016/j.enpol.2012.09.018.

Yıldırım, E., Aslan, I., Öztürk, I., 2012. Coal consumption and industrial production nexus in the USA: cointegration with two unknown structural breaks and causality approaches. Renew. Sustain. Energy Rev. 16 (8), 6123–6127. https://doi.org/10.1016/j.enpol.2012.07.002.

Yu, E.S.H., Hwang, B.K., 1984. On the relationship between energy and GNP: further results. Energy Econ. 6 (3), 186–190. https://doi.org/10.1016/S0140-9883(84)80015-3.

Yu, E.S.H., Chou, J.J., 1985. The causal relation between energy and GNP: an international comparison. J. Energy Dev. 10 (2), 249–272. https://www.jstor.org/stable/24807818?seq=1#metadata_info_tab_contents.

Dr. Güler teaches public finance and taxation and serves as an associate professor and is head of the Department of Public Finance at Nigde Omer Halisdemir University. He graduated from Cukurova University and obtained his Ph.D. from Marmara University. His research interests include taxation, public economics, economic growth, and energy economics. He has published many peer-reviewed articles on related topics.

Dr. Haykir teaches finance and economics and serves as a Vice Director of the Graduate School of Social Sciences at Nigde Omer Halisdemir University. He has two master’s degrees from the University of Delaware, USA, and holds a Ph.D. from the University of Exeter, UK. His research interests include asset pricing, applied econometrics, and corporate finance. He has published many peer-reviewed articles on related topics.

Dr. Oz works for the Turkish Ministry of Energy and Natural Resources He graduated from Cukurova University and obtained his Ph.D. from Gazi University. His research interests include economic growth and energy economics. He has published peer-reviewed articles on related topics.