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Revisiting the electricity consumption-led growth hypothesis: is the rule defied in France?

Abdulkadir Abdulrashid Rafindadi[1], Isah Buhari Aliyu[2] and Ojonugwa Usman[3*]

*Correspondence: ousman@ticaret.edu.tr

[1] Faculty of Social Sciences, Department of Economics, Usmanu Danfodiyo University, Sokoto, Nigeria
[2] Department of Accounting, Finance, and Economics, Business School, University of Huddersfield, Queensgate, Huddersfield HD1 3DH, UK
[3] Economics and Finance Application and Research Center, Department of Economics, Istanbul Ticaret University, Istanbul, Turkey

Abstract
Recent economics literature emphasises the inextricable link between economic prosperity and efficient energy supply and consumption, arguing vehemently that much of today's prosperity is predicated on secure and reliable energy use and that modern industry would grind to a halt without the necessary energy infrastructure. France is an example of an advanced country with enormous energy infrastructure. The country's economic growth has been rather sluggish in recent years, despite its robust and efficient energy production and consumption. The current study analyses empirically whether France's current sustainable electricity use defies the theoretical and empirical literature. To achieve this objective, the standard tools of growth empirics were used over the period 1961–2015. The Zivot–Andrews trended and de-trended structural break tests, as well as Autoregressive Distributed lag (ARDL) bounds testing were employed to analyse the data. The findings of this study demonstrated that France's economic growth is stimulated by electricity usage, financial development, capital, import, and export. The study sheds light on the feedback impact between economic growth and power usage as well as capital and economic growth. With these findings, we argue that it is not electricity that has ceased to serve a functional purpose in France, rather there is a need for entrepreneurial innovative capacity to create factors that require an infinite horizon for the continued use of electricity, which seems to be impeding the country's economic growth potential, among other things.

Keywords: Economic growth, Financial development, Trade, Electric power, France

1 Introduction

In the contemporary era, economies that are heavily reliant on international trade and strive for a certain level of economic growth are more vulnerable to the possibility of experiencing severe economic shocks, which slows economic progress (see Irwin and Terviö 2002; Frankel et al. 1996; Frankel and Romer 1999; Schneider 2005). The financial crisis of 2008–2009 alone has had a considerable impact on the majority of developed and emerging countries, wreaking havoc on export-dependent economies (Tang et al., 2015). Following the seminal work of Kraft and Kraft (1978), empirical studies identified a substantial link between energy consumption and economic growth that is far greater than what is predicted from international trade (see Al-mulali et al. 2014; Al-Mulali 2014; Al-mulali and Ozturk 2014; Wolde-Rufael and Menyah 2010; Mehrpooya et al.

2018; Ansong et al. 2017; Heuër 2017; Dos Santos et al. 2016; Afkhami et al. 2015; Kolhe et al. 2015; Alola et al. 2019; Usman et al. 2020, 2021).

Electricity is a necessary component of today's productive environment because there has never been a viable substitute for energy consumption that might facilitate production activities for domestic consumption or export in any given economic system (Rafindadi 2015a and b; Usman, 2022). Electricity energy, as a necessary and indispensable factor, permits the attainment of efficient and effective economic productivity, since the essentiality of energy consumption is correlated with the important factors of production, namely land, labour, and capital (Rafindadi 2016). The presence of efficient, sustainable, and sufficient electricity energy consumption in any country indicates the possibility of an increase in the country's GDP and vice versa (Adom 2011; Rafindadi and Ozturk, 2016; Rafindadi and Usman 2021).

According to Wolde-Rufael 2004; Halicioglu (2009), Al-mulali et al. (2014), and Al-Mulali (2014), achieving production optimality requires a direct link and interaction between energy sufficiency and energy efficiency. Any apparent increase in economic growth is essentially necessary by the possibility of increasing energy consumption; and therefore, established efficient and sufficient energy consumption in a country implies the existence of a fully productive economic system, which is synonymous with growth.

Recently, France is one advanced country that provides interesting case study for the role of electricity consumption in economic prosperity. In 2019, France is the seventh largest economy in the world and the third largest in Europe (IMF 2020). The country ranks second in the world in terms of nuclear energy production, after only the United States. France generates around 76% of its electricity from fully operational nuclear power reactors, with the remainder coming from renewable and fossil energy sources, respectively. In 2019, the country generated about 379.5 TWh and consumed only 432 TWh. The total electricity production was about 537.7 TWh with the nuclear share having about 71.67%, the world's highest percentage. Furthermore, about 70 TWh of France electricity is being exported to the Europe net each year. Hence, by the first half of 2021, France became the largest electricity exporter to Europe, particularly to the UK and Italy (Trade Economics, 2022). As a result of this feat, France became the world's third greatest power exporter. For example, France earned about 633 million Euro in June 2022 and increased to 824 million Euro in July 2022 (Trade Economics, 2022).

In a similar trend, the OECD report in 2019 demonstrated that since 2013, a growing tension has hampered the French economy's ability to grow at a reasonable rate. In light of the recent economic recession's massive impact on the economies of the majority of European countries, including Germany, Italy, Spain, UK, as well as other parts of the world, it is likely that France's economy will be one of the most affected in the event of a future global economic downturn, owing largely to its non-presidential status (IMF 2020). The question we asked here is why, despite France's consistent electrical supply, GDP continues to fluctuate? Has power consumption in the country ceased to have significant contributing impacts, as originally argued by Kraft and Kraft (1978) and more recently by Al-mulali et al. (2014); Almulali (2014); Al-mulali and Ozturk (2014); Apinran et al. (2022) and Hassan et al. (2022)?

The purpose of this study is to determine whether electricity usage is consistent with the advanced economy like France's economic growth prospects. The study specifically examines the extent to which electricity consumption contributes to the economic growth prospects of France, if at all. To distinguish this study from others, a comparative multivariate strategy was used, in which factors pertaining to France's financial development, capital–labour ratio, and trade openness were included in the line of analysis.

The remaining sections of this work are organised in four sections. Section 2 covers the relevant (empirical) literature in the topic, whereas Sect. 3 discusses the methods used in the study. Section 4 presents and discusses the empirical findings from the various analyses undertaken in this study. Section 5 presents the study's conclusion and policy implications.

2 Literature review

In the expanding fields of economic activity in economies world over, electricity has become the preferred and dominating energy source. It has been a vital contributor to the rise in living standards and has aided technological and scientific advancements. As a result, this type of energy is widely seen as being particularly crucial for economic development. The econometric literature on energy is well-documented regarding the causal relationship between various forms of energy use and GDP growth (e.g., see Ozturk 2010). Diverse studies examined a range of countries, time periods, and energy proxy variables, among other things. These investigations frequently produce contradicting empirical findings. Indeed, even the direction of causality, as well as its long-term vs. short-term impact on energy policy, varies between the studies. Policy considerations are influenced by the sort of causal relationship or the lack thereof. We will review some of the prior research on the causal links between economic growth and power demand in the next paragraphs.

Yoo (2006) investigates the short- and long-run causal relationships between power consumption and economic growth in Korea through the use of cointegration and error-correction models. From 1970 until 2002, the author uses annual data. The aggregated findings indicate that energy use and economic growth are causally related in both directions. This demonstrates that greater electricity consumption has a direct effect on economic growth, which in turn fuels increased electricity consumption. Yoo (2005) earlier discovered comparable results in a sample of ASEAN 4 member states (i.e. Malaysia, Indonesia, Thailand, and Singapore).

Yoo and Kwak (2010) examine the causal association between electricity consumption and economic growth in Brazil, Argentina, Chile, Ecuador, Columbia, Venezuela, and Peru, using three stage approach (cointegration, Granger causality, and error correction mechanism). The data indicate that the connection between energy use and economic growth varies significantly between countries. There is a short-run unidirectional causality between electricity use and real GDP for Argentina, Chile, Brazil, Ecuador, and Columbia. This demonstrates that increased energy use has a direct effect on the economic growth of those countries. Electricity consumption and economic growth in Venezuela are causally linked in both directions, meaning that higher energy use directly impacts economic growth, which in turn stimulates increased energy consumption. There are no causal relationships in Peru, on the other hand.

Gurgul and Lach (2012) investigate whether energy use and GDP are causally intertwined in Poland. To ensure the causal relationships remained stable throughout time, the authors conducted their research in a three-dimensional framework using quarterly data from Q1:2000 to Q4:2009. In their findings, they observed a feedback effect between total electricity use and GDP, as well as between total electricity consumption and employment. Additionally, they observed unidirectional causal links between industrial electricity use and employment, but none between industrial electricity consumption and GDP.

Halkos and Tzeremes (2014) used a panel of 36 countries from 1990 to 2011 to investigate the impact of renewable electricity usage on continental GDP growth prospects. Throughout the sample size, they discovered that the effects of renewable energy had a substantially higher increasing effect on GDP. However, after a certain point, a reasonable level of stabilisation from non-renewable energy consumption to GDP growth rate was identified. The research also found that there are significant differences across emerging markets, developing nations, and mature economies. The link was nonlinear in these three categories, implying that the amount of development obtained by these three categories does not guarantee that renewable energy use will continue to have an impact on their GDP. Caraiani et al. (2015) made contrary findings on a sample of 5 emerging European countries implying that energy consumption and economic growth in the chosen countries are linked.

To support the impact of electricity consumption on economic growth, Karanfil and Li (2015) investigated the short- and long-run effects of electricity consumption and economic activity in a selected sample of 160 countries from 1980 to 2010. The study's major goal was to determine the dynamic consequences of continental electricity dependence and how this level of dependence could assist in achieving desired level of urbanisation and GDP growth. The study's findings established that the feedback hypothesis exists in the long run for the vast majority of the sample size. The authors identified unidirectional causality in the short-run between economic growth and electricity consumption in the Pacific, East Asia, North Africa, the Middle East, and lower-middle-income countries. The neutrality hypothesis was also found in sub-Saharan Africa, North America, and upper-middle income nations, according to the study. They also discovered that there was no evidence of growth hypothesis in any of the examined strata. Their study's Granger causality finding revealed a range of outcomes in terms of urbanisation and electricity net import. This was shown to differ significantly within the subsample, demonstrating that institutional efficiency, national income strata, and other regional characteristics all influence economic growth. However, this finding revealed that the electricity–growth nexus is very susceptible to regional variances, country income levels, urbanisation levels, and the electricity reliance ratio. The study revealed that in wealthy countries, the association between electricity consumption and economic growth has primarily short-term consequences, whereas in low-income economies, the relationship has long-term consequences. Similarly, increasing electricity consumption induced urbanisation in high-income countries, while higher electricity consumption induced urbanisation in sub-Saharan African continents.

Oztürk and Aslan (2015) examined a sample of 23 high-income corporate entities from OECD countries between 1960 and 2005 using the nonlinear unit root test. Their study aims to identify the dynamics of the per capita power consumption of selected samples. The authors' findings established the presence of nonlinear behaviour in 70%

of the sample's electricity consumption. Similar findings were made, revealing how the electricity consumption processes in 12 countries were non-stationary to varied degrees. According to the authors, power demand shocks are a distinct possibility, with long- and short-term implications for electrical policy difficulties. In comparison, a stationary process was seen in 19 OECD countries, indicating that while energy conservation efforts are anticipated to have a short-term effect, energy consumption is expected to resume its previous level in the long run.

Ziaei (2015) examined the relationship between energy use, GDP growth, financial development, and carbon dioxide emissions. The author chose the financial crisis period as the objective base year to make a comparative study from 1989 to 2011 employing a panel of 13 European and 12 East Asian countries. The study's findings demonstrated how the total influence of CO2 emissions and energy consumption in all samples was shown to deviate significantly from other forecast parameters included in the study. On the other hand, the panel comparative result indicated the presence of large shocks in energy consumption and CO2 emissions. Financial metrics used in the individual samples were found to be deficient, owing mostly to the consequences of the financial crisis. The most intriguing aspect of their study was their discovery that the severity of energy consumption shocks on stock return rates in European continents is greater in East Asian countries than in Oceania. This conclusion prompted the study to investigate the effect of stock return rate shocks on energy demand in East Asia and the Oceanian continents.

In their seminal research, Omri et al. (2015) utilised the dynamic panel simultaneous equation on a sample of 17 advanced and developing economies to examine the dynamic causal relationship between electricity consumption, nuclear energy, and renewable energy. The authors' unique research findings conclusively demonstrated the supremacy of nuclear energy consumption as the primary driver driving economic growth in Belgium and Spain, while finding the opposite in Canada, Bulgaria, Sweden, and Netherlands. Surprisingly, a bidirectional discovery regarding the U.S, Argentina, France, Brazil, and Pakistan was made. In the second area of their analysis, they discovered that renewable energy consumption is the primary element stimulating economic growth in India, Hungary, Netherlands, Japan, and Sweden.

Al-mulali and Mohammed (2015) investigated whether long-run and short-run sector-by-sector GDP growth can influence energy consumption in 16 emerging economies between 1980 and 2010. The authors' findings revealed a bidirectional causal relationship between oil consumption and three critical sectors of the economy. Similar findings were made with natural gas usage and the three industries represented in the sample size. In the case of coal usage, it was determined that the same bidirectional causal relationship exists solely with the service sector. Additionally, the study discovered a positive association between renewable energy usage and the value of manufacturing activities. The same discovery was made in the manufacturing and service sectors. The existence of a unidirectional relationship was discovered solely because of oil consumption and the agriculture sector's value. The study's result emphasised how renewable energy consumption has dual effects that are powerful causal drivers of economic growth and can have a significant impact on mitigating environmental deterioration. Adom and Amuakwa-Mensah (2016) and Adom et al., (2012) all report comparable findings.

In recent times, several studies have examine the role of financial systems and energy consumption on output growth. For example, Ibrahim and Alagidede (2018) and Mukhtarov et al. (2020) show that increase in financial system leads to an increase in economic growth possibly through the channel of energy consumption and technological improvements and innovations. Moreover, as reported via a study by Asteriou and Spanos (2019), the level at which financial development affects economic growth is dependent on the economic conditions. For example, for 26 countries in the EU, it was found that financial development increases growth before the period of financial crisis, while the post-crisis era showed that financial development was found to be counter growth. Hoang (2021), utilising a Bayesian approach, re-examined whether financial development and energy consumption affect economic growth of ASEAN + 6 countries from 1980 to 2016. Their study's findings indicate that both financial development and energy consumption have a significant and beneficial effect on economic growth of the countries. In addition, the Conversation hypothesis was supported by evidence for a one-way relationship between economic growth and energy use in the countries.

Regarding electricity consumption and economic growth, Opeyemi and Paul-Francois (2019) examined the short- and long-run correlations, as well as causative relationships, between electricity consumption, trade openness, and South Africa's economic growth from 1984 to 2015 using an autoregressive distributed lag (ARDL) model. Their empirical findings indicate that both energy consumption and trade openness have a positive and significant effect on economic growth over the long run. According to a Granger causality test, electricity consumption and trade openness both affect economic development independently of any feedback effects. This demonstrated that boosting energy output and trade openness had a significant positive effect on South Africa's economy. Kose et al. (2020) examined the role of R&D in achieving sustainable economic growth in the EU. The study found in addition to R&D that both renewable and non-renewable energy are also sources of growth in the long run. Dogan et al. (2020), while revisiting the empirical work of Inglesi-Lots (2016) for OECD countries, submitted that renewable energy increases growth in lower and lower-middle quantiles, but decreases in the middle, higher-middle, and higher quantiles if renewable energy is considered based on absolute value. Hassan et al. (2022) investigated the effect of electricity consumption on Portugal, France, and Finland by capturing the effects of structural breaks in the series. The results indicated that the long- and short-run effects of electricity on growth in Portugal and Finland are positive and significant, while in France electricity consumption only increases growth in the long run.

Apinran et al. (2022) using a dynamic ARDL modelling technique show that electricity consumption stimulates economic growth, while CO_2 emission reduces economic growth in Nigeria. Furthermore, Wang et al. (2022) investigated the evolutionary trends and spatial pattern of 4 kinds of residential energy consumption in China over the period 2000 to 2019. Having observed that a standard deviational ellipse provides a dynamic evolution patterns of residential energy consumption, suggested that electricity should be prioritised in the development of residential energy for growth. Balcilar et al. (2022a) examine the effect of green energy consumption and investment on economic growth in OECD countries within the framework of the standard tools of growth empirics. The results revealed that although the effect of green energy is positive and significant but their impacts on growth are small and heterogeneous across times. These results suggest that the development toward green is not yet sustainable to aggressively mitigate greenhouse effect. From another perspective, Balcilar et al. (2022b) show that due to the relationship between energy and economic growth as established extensively in the literature, energy market shocks are found to affect economic activity in the US at different periods of financial conditions.

3 Methodology

3.1 Data, variables, and the models

The methodology used in this study was based the standard tools of growth empirics and the sample period spans from 1961 to 2015. The selection of this period was based on the data availability for France. In light of the method's inherent characteristics and the qualities of time series data employed, this study examined two distinct models for dealing with structural breaks. While the study used the ARDL bounds testing technique to cointegration for the long-run and short-run dynamics, this approach was confirmed using the Johansen cointegration test. We detect direction of causation of the forecast variables using the VECM Granger causality test. Using the standard tools of growth empirics, we specify the following functional forms:

$$Y_t = f(EC_t, F_t, K_t, TRD_t), \tag{1}$$

where Y denotes the real GDP per capita, EC is the electric power consumption measured in kWh per capita, F is the domestic credit to the private sector as the percentage of GDP, K is the natural real capital stock per capita. TRD represents trade measured in three ways: first, TO which is the trade openness, i.e. the sum of total exports and imports as the percentage of GDP. Second, EX which denotes the total exports per capita, defined as the total exports of goods and services in current USD divided by the total population and t is the time period. The third way is IM which is the total import per capita, defined as the total imports of goods and services in current USD divided by the total population. To ensure consistency, the study transformed all the series into natural log specification. This specification is then modelled as follows:

$$\ln Y_t = \beta_1 + \beta_2 \ln EC_t + \beta_3 \ln F_t + \beta_4 \ln K_t + \beta_5 \ln TRD_t + \mu_t \tag{2}$$

where ln denotes the natural logarithms of all the variables at time t as defined in Eq. (1) with their respective parameters, i.e. $\beta_1 - \beta_5$ and μ is the error term in the model. Furthermore, we consulted the database of the World Bank's World Development Indicators (WDI) for compiling the data for this study, namely: real GDP per capita, domestic credit to the private sector, capital stock per capita, power (electric) consumption (kg of oil equivalent) per capita, exports and imports per capita, and trade openness. All these variables were measured in real terms except domestic credit to the private sector and trade openness, which are not. The period chosen was based on the availability of data for France. For example, electricity consumption and capital stock are available up the period selected for this study.

This paper proceeds to estimate model (2) utilising Pesaran et al. (2001) developed ARDL bounds test approach to cointegration. The study employs this methodology because of its superiority over all other methods of linear regression estimation, including the notable Johansen and Juselius (1990) approach.[1] One of the primary, distinguishing characteristics and superiority of the ARDL model over the Johansen and Juselius method is its capacity to discern between the values of the dependent and independent variables in such a sparse manner. To take this advantage for obtaining a robust solution, Eq. 2 is modelled using the unconditional error correction model (UECM). The following is the specification[2]:

$$\begin{aligned}\Delta \ln Y_t =& c_1 + \sum_{i=0}^{p} d_{11,i}\Delta \ln Y_{t-i} + \sum_{i=0}^{p} d_{12,i}\Delta \ln EC_{t-i} + \sum_{i=0}^{p} d_{13,i}\Delta \ln F_{t-i}\\ &+ \sum_{i=0}^{p} d_{14,i}\Delta \ln K_{t-i} + \sum_{i=0}^{p} d_{15,i}\Delta \ln TRD_{t-i}\\ &+ \pi_{11}\ln Y_{t-1} + \pi_{12}\ln EC_{t-1} + \pi_{13}\ln F_{t-1}\\ &+ \pi_{14}\ln K_{t-1} + \pi_{15}\ln TRD_{t-1} + \pi_{1D}DUM_t + u_{1t}\end{aligned} \tag{3}$$

$$\begin{aligned}\Delta \ln EC_t =& c_2 + \sum_{i=0}^{p} d_{21,i}\Delta \ln Y_{t-i} + \sum_{i=0}^{p} d_{22,i}\Delta \ln EC_{t-i}\\ &+ \sum_{i=0}^{p} d_{23,i}\Delta \ln F_{t-i} + \sum_{i=0}^{p} d_{24,i}\Delta \ln K_{t-i}\\ &+ \sum_{i=0}^{p} d_{25,i}\Delta \ln TRD_{t-i} + \pi_{21}\ln Y_{t-1} + \pi_{22}\ln EC_{t-1}\\ &+ \pi_{23}\ln F_{t-1} + \pi_{24}\ln K_{t-1} + \pi_{25}\ln TRD_{t-1} + \pi_{2D}DUM_t + u_{2t}\,,\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta \ln F_t =& c_3 + \sum_{i=0}^{p} d_{31,i}\Delta \ln Y_{t-i} + \sum_{i=0}^{p} d_{32,i}\Delta \ln EC_{t-i}\\ &+ \sum_{i=0}^{p} d_{33,i}\Delta \ln F_{t-i} + \sum_{i=0}^{p} d_{34,i}\Delta \ln K_{t-i}\\ &+ \sum_{i=0}^{p} d_{35,i}\Delta \ln TRD_{t-i} + \pi_{31}\ln Y_{t-1} + \pi_{32}\ln EC_{t-1}\\ &+ \pi_{33}\ln F_{t-1} + \pi_{34}\ln K_{t-1} + \pi_{35}\ln TRD_{t-1} + \pi_{3D}DUM_t + u_{3t},\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta \ln K_t =& c_4 + \sum_{i=0}^{p} d_{41,i}\Delta \ln Y_{t-i} + \sum_{i=0}^{p} d_{42,i}\Delta \ln EC_{t-i}\\ &+ \sum_{i=0}^{p} d_{43,i}\Delta \ln F_{t-i} + \sum_{i=0}^{p} d_{44,i}\Delta \ln K_{t-i}\\ &+ \sum_{i=0}^{p} d_{45,i}\Delta \ln TRD_{t-i} + \pi_{41}\ln Y_{t-1}\\ &+ \pi_{42}\ln EC_{t-1} + \pi_{43}\ln F_{t-1} + \pi_{44}\ln K_{t-1}\\ &+ \pi_{45}\ln TRD_{t-1} + \pi_{4D}DUM_t + u_{4t}\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta \ln TRD_t =& c_5 + \sum_{i=0}^{p} d_{51,i}\Delta \ln Y_{t-i} + \sum_{i=0}^{p} d_{52,i}\Delta \ln EC_{t-i} + \sum_{i=0}^{p} d_{53,i}\Delta \ln F_{t-i}\\ &+ \sum_{i=0}^{p} d_{54,i}\Delta \ln K_{t-i} + \sum_{i=0}^{p} d_{55,i}\Delta \ln TRD_{t-i} + \pi_{51}\ln Y_{t-1}\\ &+ \pi_{52}\ln EC_{t-1} + \pi_{53}\ln F_{t-1} + \pi_{54}\ln K_{t-1} + \pi_{55}\ln TRD_{t-1} + \pi_{5D}DUM_t + u_{5t}\end{aligned} \tag{7}$$

[1] Among the advantages cited by Ghatak and Siddiki (2001), is that the ARDL model is superior in terms of differentiating between the values of the dependent and independent variables. It can also produce strong estimates/results with a small sample data. This contrasts with the Johansen cointegration technique, which takes a significant amount of data to produce a reasonable result. Additionally, it is worth noting that the ARDL bound test does not need the estimation of variables to be integrated in the same order. This implies that I(1) and I(0) variables may, nevertheless, produce valid and robust results. Again, this contrasts with the Johansen and Juselius technique that does not accommodate I(1) and I(0) variables. The ARDL model is preferable when estimating dynamic long-run and short-run outcomes simultaneously without deteriorations (Bentzen and Engsted 2001).

[2] For brevity, Eqs. (3), (4), (5), (6), (7) are estimated based on three trade (lnTRD) measures, namely; lnTO, lnEX, and lnIM as previously defined.

In models 3 to 7 above, the first part of each equation denotes the short-term dynamics while the second part captures the long-run dynamics. $\Delta \text{and} c_1 to c_5$ signify first differences and drifting elements, respectively. The lag length is given by p and u is the white noise residuals.[3] DUM refers to the dummy variables required to capture the break dates in the series.[4] The long-run parameters are obtained by $\beta_i = \pi_{ii}/(1 - \sum_{k=1}^{p} d_{ii,k}), i = 1, .., 5$ while d_{ij} represents the short-run parameters. According to Pesaran et al (2001), two critical stages must be followed in order to proceed with the estimating process of the ARDL model, namely: (1) doing an F-test to determine the combined significance of the lagged variables. (2) Determining the null hypothesis for the absence of a long-run relationship by comparing it to the alternative hypothesis, i.e. $H_0 : \pi_{i1} = \pi_{i2} = \pi_{i3} = \pi_{i4} = \pi_{i5} = 0$, against $H_1 : \pi_{ij} \neq 0, j = 1, .., 5$.

Following the completion of these two stages, the lower and upper critical boundaries for the F-test are established in accordance with Pesaran et al (2001). These guidelines established that, because the lower bound's critical values are I(0) and the upper bound's critical values are I(1), the rule indicates that whenever the F-statistics are statistically greater than zero, the null hypothesis is rejected.[5] However, if the F-statistics are less than the lower bound, the null hypothesis of no long-run relationship is not rejected in this situation.

Finally, the error correction model (ECM) technique is used to estimate the variables' long- and short-run dynamics. The vector error correction model (VECM) and Granger causality analysis can be used to detect the causational link between capital all the vaiables considered in this study as empirically described in Eq. 8 below:

$$\begin{pmatrix} \Delta \ln Y_t \\ \Delta \ln EC_t \\ \Delta \ln F_t \\ \Delta \ln K_t \\ \Delta \ln TRD_t \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{pmatrix} + \begin{pmatrix} d_{11,1} & \cdots & d_{15,1} \\ \vdots & \ddots & \vdots \\ d_{51,1} & \cdots & d_{55,1} \end{pmatrix} \begin{pmatrix} \Delta \ln Y_{t-1} \\ \Delta \ln EC_{t-1} \\ \Delta \ln F_{t-1} \\ \Delta \ln K_{t-1} \\ \Delta \ln TRD_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} d_{11,p} & \cdots & d_{15,p} \\ \vdots & \ddots & \vdots \\ d_{51,p} & \cdots & d_{55,p} \end{pmatrix} \begin{pmatrix} \Delta \ln Y_{t-p} \\ \Delta \ln EC_{t-p} \\ \Delta \ln F_{t-p} \\ \Delta \ln K_{t-p} \\ \Delta \ln TRD_{t-p} \end{pmatrix} + \begin{pmatrix} \gamma_1 ECM_{1t-1} \\ \gamma_2 ECM_{2t-1} \\ \gamma_3 ECM_{3t-1} \\ \gamma_4 ECM_{4t-1} \\ \gamma_5 ECM_{5t-1} \end{pmatrix} \begin{pmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \\ \mu_{5t} \end{pmatrix}. \tag{8}$$

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[3] Pesaran et al. (2001) emphasised on the significance of balancing the selected lag length.

[4] Due to the CMR unit root test, which assumes a single unknown break in the series, the ARDL F-test model includes a dummy variable.

[5] When the estimated F statistic falls between the lower and higher boundaries, the result is often regarded as inconclusive. As a result of this, another effective method for determining the presence of cointegration between variables is to examine the substantial negative outcome of the lagged error correction term (see Kremers et al. 1992).

Table 1 Unit root tests results

Variables	MZa	MZt	MSB	MPT
$\ln Y_t$	− 5.24913 (1)	− 1.32343	0.25212	16.2964
$\ln EC_t$	0.42424 (2)	0.23999	0.56569	76.3302
$\ln F_t$	− 0.19402 (5)	− 0.30163	1.55459	441.331
$\ln K_t$	− 7.01357 (1)	− 1.82956	0.26086	13.0459
$\ln TO_t$	− 7.95355 (1)	− 1.78050	0.22386	12.0059
$\ln EX_t$	− 5.94145 (3)	− 1.49934	0.25235	15.0515
$\ln IM_t$	− 12.5424 (1)	− 2.34799	0.18720	8.09920
$\Delta \ln Y_t$	− 19.3972(2)**	− 3.11199	0.16044	4.71158
$\Delta \ln EC_t$	− 23.4457 (1)*	− 3.40809	0.14536	3.98105
$\Delta \ln F_t$	− 27.4054 (2)*	− 3.70167	0.13507	3.32534
$\Delta \ln K_t$	− 23.7261 (1)*	− 3.44045	0.14501	3.86358
$\Delta \ln TO_t$	− 23.8173 (2)*	− 3.44744	0.14475	3.84666
$\Delta \ln EX_t$	− 23.3170 (3)*	− 3.41408	0.14642	3.91038
$\Delta \ln IM_t$	− 18.8370 (2)**	− 3.05442	0.16215	4.92560

* and ** indicate p-values at 1% and 5% levels. Lag length of variables is shown in small parentheses

Table 2 Zivot–Andrews structural break trended unit root test

Variable	At level		At 1st difference	
	T-stat	Break year	*T*-stat	Break year
$\ln Y_t$	− 1.543 (1)	1985	− 6.156 (2)*	1982
$\ln EC_t$	− 3.738 (2)	2000	− 5.442 (1)**	1986
$\ln F_t$	− 3.201 (1)	1978	− 11.839 (4)*	1978
$\ln K_t$	− 4.120 (3)	1981	− 5.499 (1)**	1985
$\ln TO_t$	− 4.167 (3)	1998	− 6.719 (3)*	1987
$\ln EX_t$	− 4.332 (1)	1997	− 6.841 (2)*	1988
$\ln IM_t$	− 4.195 (2)	1998	− 7.182 (1)*	1976

* and ** indicate p-values at 1% and 5% levels. Lag length of variables is shown in small parentheses

In model 8, all the variables remain as previously defined. TRD_t is the measure of trade in different ways as earlier defined. Δ is the difference operator and ln is the natural logarithms of variables. Note that the notations in the matrices denote the parameter for each of the five variables both in the long run and the associated short run as well as their error terms, μ_i, $i = 1, .., 5$. Furthermore, the ECM_{it-1} is the error correction model that is obtained from the estimated results of the long-run relationship among the variable. The ECM_{it-1} is an indication of how significant and valid the results of the long-run dynamics are. It suggests the validity, strength, and the fitness of the model. It also validates the acceptability or otherwise of the long-run coefficient results. The T-test and F-test statistics are used to determine first-differences, while lagged independent variables are used to determine the variables' short-run causal link. In the case of France, this study used time series data from 1961 to 2015.

Table 3 CMR de-trended structural break unit root test

Variable	Innovative outliers				Additive outlier			
	T-stat	TB1	TB2	Conclusion	*T*-statistic	TB1	TB2	Conclusion
ln EC_t	− 3.536 (2)	1981	1992	Unit root	− 8.276 (2)*	1976	1989	Stationary
ln Y_t	− 2.993 (3)	1991	2001	Unit root	− 5.523 (1)**	1991	1998	Stationary
ln F_t	− 3.301 (3)	1975	2000	Unit root	− 5.699 (2)*	1975	1978	Stationary
ln K_t	− 4.763 (1)	1991	2002	Unit root	− 5.893 (1)*	1986	1991	Stationary
ln TO_t	− 3.426 (2)	1986	1997	Unit root	− 6.481 (2)*	1991	1998	Stationary
ln EX_t	− 3.387 (1)	1985	1996	Unit root	− 5.897 (2)*	1995	1998	Stationary
ln IM_t	− 3.454 (3)	1986	1997	Unit root	− 6.044 (4)**	1991	1998	Stationary

* and ** indicate p-values at 1% and 5% levels. Lag length of variables is shown in small parentheses

4 Empirical results and discussions

4.1 Preliminary analysis

The initial step in this section was to verify the variables' unit root properties. This is critical to obtaining results that are robust and error-free. This study ensured this, first, by employing the Ng–Perron unit root test, which is well-suited for small sample data sets. This unit root test produces consistent and reliable empirical results and, because to its explanatory power, it outperforms the ADF, PP, DF-GLS, and KPPS. Table 1 summarises the results of the Ng–Perron unit root. The table demonstrates that while all the series are non-stationary at the levels (with intercept and trend), and we can reject the null hypothesis of unit root at the first difference. This indicates that all variables are cointegrated at I (1) at 5% and 1% levels, respectively.

However, structured breaks are quite common in almost all time series data. In this regard, unit root tests such as the Ng–Perron and augmented Dickey–Fuller tests are prone to producing biased results. To address this shortcoming, the current study used the Zivot and Andrews (1992) unit root test (here after, ZA test), which is capable of accounting for a single unknown structural break. The ZA test's technical operation is based on its capacity to recognise existing break dates as they occur in the series. The technical direction of this test's operation is to ensure that the T-statistic is estimated first, in the same manner that the ADF test is determined. The break dates are then chosen based on the evidence that is discovered to be favourable to the null hypothesis. To ensure that this test runs efficiently, critical values identical to those used in the ADF unit root test are used. Table 2 contains the empirical results of this test as conducted in this study.

According to Table 2, all variables are non-stationary at the level. This discovery demonstrates unequivocally that the series contains structural breaks. The ZA test was used to determine this. The break dates detected using this test are 1982, 1986, 1978, 1985, 1988, 1976, and 1987 which correspond to economic growth, electricity consumption, exports, imports, capital, financial development, and trade openness, respectively. These variables attained stationarity at the first difference, demonstrating the robustness of the unit root analysis and, hence, verifying the fact that all variables are integrated in order of I(1).

The primary limitation of the previous analysis on Table 2 (i.e. ZA unit root test) is that it only provides structural break information for a single structural break in a series

Table 4 ARDL cointegration test results

Cointegration: bound testing approach				Diagnostics			
Models estimated	**Optimal lag length**	**Structural break**	***F*-statistics**	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}	χ^2_{SERIAL}
$F_{\ln Y}(lnY/lnE, lnF, lnK, \ln TO)$	2, 1, 2, 2, 1	1985	5.402***	1.0943	[1]: 0.2647	[3]: 0.1304	[2]: 0.5558
$F_{\ln EC}(\ln EC/lnY, lnF, lnK, \ln TO)$	2, 2, 2, 2, 2	2000	5.571**	1.5935	[1]: 0.3314	[1]: 0.9617	[3]: 1.4889
$F_{\ln F}(lnF/lnY, \ln EC, lnK, \ln TO)$	2, 1, 2, 2, 1	1978	5.992**	2.6725	[1]: 3.5300	[4]: 0.0931	[1]: 1.8095
$F_{\ln K}(lnK/lnY, \ln EC, lnF, \ln TO)$	2, 2, 2, 2, 2	1981	12.534*	0.6259	[1]: 1.2557	[1]: 0.2316	[1]: 0.3129
$F_{\ln TR}(\ln TO/lnY, \ln EC, lnF, lnK)$	2, 1, 2, 2, 1	1998	1.643	2.4347	[2]: 0.0206	[4]: 1.4110	[2]: 0.0872
$F_{\ln Y}(lnY/lnEC, lnF, lnK, lnEX)$	2, 1, 2, 2, 2	1985	6.68**	2.0518	[1]: 0.4499	[1]: 0.5662	[1]: 0.2249
$F_{\ln EC}(\ln EC/lnY, lnF, lnK, lnEX)$	2, 2, 1, 1, 2	2000	10.052*	0.2217	[1]: 0.0770	[2]: 0.4295	[2]: 1.7076
$F_{\ln F}(lnF/lnY, \ln EC, lnK, lnEX)$	2, 2, 2, 1, 2	1978	6.248**	1.6474	[1]: 0.3144	[2]: 5.6190	[1]: 2.1829
$F_{\ln K}(lnK/lnY, \ln EC, lnF, lnEX)$	2, 2, 2, 2, 1	1981	5.379***	0.8848	[1]: 0.3045	[2]: 0.2216	[2]: 0.9832
$F_{\ln EX}(lnEX/lnY, \ln EC, lnF, lnK)$	2, 1, 2, 1, 2	1987	3.551	3.4767	[1]: 0.5088	[1]: 0.2716	[1]: 0.0044
$F_{\ln Y}(lnY/\ln EC, lnF, lnK, lnIM)$	2, 1, 2, 1, 2,	1985	6.450**	0.6380	[1]: 0.3788	[1]: 0.6389	[1]: 3.1782
$F_{\ln EC}(\ln EC/lnY, lnF, lnK, lnIM)$	2, 2, 1, 1, 2	2000	5.358***	0.5558	[1]: 1.7061	[1]: 0.2985	[1]: 1.4522
$F_{\ln F}(lnF/lnY, \ln EC, lnK, lnIM)$	2, 1, 2, 2, 2	1978	12.145*	1.5836	[1]: 0.0720	[1]: 3.6646	[4]: 1.5827
$F_{\ln K}(lnK/lnY, \ln EC, lnF, lnIM)$	2, 2, 2, 2, 1	1981	5.962**	4.6148	[4]: 0.5922	[3]: 0.0044	[2]: 1.1102
$F_{\ln IM}(lnIM/lnY, \ln EC, lnF, lnK)$	2, 1, 2, 1, 2,	1988	0.591	0.8152	[1]: 0.3114	[1]: 0.9130	[1]: 0.1043
Significant levels	Critical values						
	Lower bounds I(0)	Upper bounds I(1)					
1 Percent level	6.053	7.458					
5 Percent level	4.450	5.560					
10 Percent level	3.740	4.780					

1%, 5%, and 10% significant p-values are, respectively, indicated by *, **, and ***. The optimal lag length is determined using the AIC. While the [] refers to the order of diagnostic tests. # denotes the critical values following Narayan (2005)

and cannot provide structural break information for multiple structural breaks that may exist within a single set of data. To address this weakness, and in light of the possibility of several breaks within dataset we have in this study, this study applied the Clemente et al. (1998) test (CMR test, here after) which exposes and rectify multiple structural breaks within a series. However, this test is distinguished by its use of the additive outliers (AO) method. This is done in an attempt by the model to plug in rapid changes in the mean of the series while also affecting important gradual changes in the mean of the variables. To assure the process's efficacy, the innovation outliers (IO) model is rigorously tested using the model estimation mechanism's explicit and strict requirements. Despite this, the

Table 5 Johansen cointegration test results

Hypothesis	Trace statistic	Max. Eigen value
$\ln Y_t = f(\ln EC_t, lnF_t, lnK_t, \ln TO_t)$		
$R=0$	134.308*	57.7443*
$R \leq 1$	76.5643*	38.4684*
$R \leq 2$	38.0959	24.9707
$R \leq 3$	13.1251	8.7558
$R \leq 4$	4.3693	4.3693
$\ln Y_t = f(\ln EC_t, lnF_t, lnK_t, \ln EX_t)$		
$R=0$	141.3335*	68.4811*
$R \leq 1$	72.8524*	34.3347**
$R \leq 2$	38.5176	24.3003
$R \leq 3$	14.2173	8.6101
$R \leq 4$	5.6071	5.6071
$\ln Y_t = f(\ln EC_t, lnF_t, lnK_t, \ln IM_t)$		
$R=0$	127.8559*	45.0066*
$R \leq 1$	82.8493*	38.4511*
$R \leq 2$	44.3981**	31.6897*
$R \leq 3$	12.7084	9.7468
$R \leq 4$	2.9615	2.9615

Significant values at 1% and 5% levels are indicated by * and **, respectively

model demonstrated unequivocally that the additive outlier model should be favoured for series with significant structural deviations, as opposed to those with gradual shifts.

Table 3 summarises the outcomes of the analysis used to perform this estimation. The findings demonstrated that the variables under consideration were non-stationary in the presence of dual structural breaks at level, implying the presence of a unit root problem. After the CMR test dual structural breaks model is executed, all variables in the model become stationary at first difference. In this regard, the analysis concludes that the series are integrated in the same order, namely I(1).

The ARDL model is utilised due to its efficacy and capacity to reveal the presence of cointegration among the selected variables in the presence of structural fractures (see Pesaran, 2015). Additionally, the AIC criterion is employed for lag selection. Based on the analysis conducted during the lag selection activity, the study determined that the optimal lag duration is two. After concluding the lag selection process, the study moves on to calculating the *F*-statistic. The findings from the *F*-statistics will be able to represent the presence or absence of cointegration between the series. To this end, it is self-evident that if the calculated *F*-statistic exceeds the critical boundaries, the investigation will proceed to reject the hypothesis of no cointegration, and vice versa.

Table 4 summarises the results of the ARDL cointegration analysis. The calculated *F*-statistical values exceeded the upper critical boundaries at the 1% and 5% levels, respectively. This research demonstrates unequivocally the existence of cointegration. When financial development, electricity consumption, economic growth, and capital were considered as dependent variables, the study discovered the existence of four cointegrating vectors. A similar pattern of development is observed with respect to imports and models of trade openness.

Table 6 Long- and short-run results (dependent variable = ln Y_t)

Long run analysis						
Variables	**Coeff.**	***T*-stat**	**Coeff.**	***T*-stat**	**Coeff.**	***T*-stat**
Constant	4.7345*	24.5898	5.2010*	19.5478	4.9423*	23.940
ln F_t	0.0163**	2.2559	0.2815*	14.5480	0.2708*	14.774
ln EC_t	0.2744*	14.688	0.0200**	2.7073	0.0135***	1.9216
ln K_t	0.1798*	6.6848	0.0831**	2.1247	0.1237*	3.9669
ln TO_t	–	–	–	–	0.1725*	9.1224
ln EX_t	0.1487*	8.7552	–		–	–
ln IM_t	–	–	0.1774*	7.7777	–	–
Short-run analysis						
Variables	**Coeff.**	***T*-stat**	**Coeff.**	***T*-stat**	**Coeff.**	***T*-stat**
Constant	0.0038**	2.3806	0.0051*	2.8994	0.0038**	2.3056
ln F_t	0.0056	1.1929	0.0056	1.0826	0.0059	1.2437
ln EC_t	0.1334*	3.1069	0.1722*	3.2487	0.1306**	2.7187
ln K_t	0.1802*	5.0623	0.1354**	2.5551	0.1242*	2.8709
ln TO_t	–	–	–	–	0.1790*	4.5446
ln EX_t	0.1572*	5.1486	–	–	–	–
ln IM_t	–	–	0.1204*	2.9153	–	–
ECM_{t-1}	− 0.3686*	− 2.4552	− 0.5306*	− 3.2308	− 0.4395*	− 2.6129
R^2	0.8571		0.8191		0.8528	
F-statistic	43.2053*		32.6186*		41.7260*	
D. W	1.5509		1.5359		1.6520	
Short-run diagnostic tests						
Test	***F*-stat**	***P*-value**	***F*-stat**	***P*-value**	***F*-stat**	***P*-value**
χ^2_{NORMAL}	5.4026	0.0671	3.2525	0.1966	1.2038	0.1212
χ^2_{SERIAL}	2.5905	0.0694	0.3153	0.8339	2.1414	0.1462
χ^2_{ARCH}	1.7716	0.1909	1.9436	0.1712	1.7056	0.1996
χ^2_{WHITE}	3.1184	0.0664	1.1671	0.1491	2.3603	0.0531
χ^2_{REMSAY}	1.1955	0.2399	0.5363	0.5951	0.1058	0.9163

*, ** and *** indicate significant values at 1%, 5%, and 10%, respectively

Apart from the previously mentioned application of the ARDL bounds testing approach to the cointegration test, and in order to obtain a compelling and robust conclusion, the current study conducted a comparative investigation of the cointegration determination process. As a result, the Johansen cointegration test was used to determine the series' long-run relationship. Table 5 summarises the findings from this empirical study. According to the results in that table, both the Maximum Eigenvalue and the Trace statistics are significant. This reinforces the importance of rejecting the null hypothesis of no cointegration, hence validating the existence of cointegrating vectors between the series, as the ARDL results clearly indicate. Concerning this conclusion, the study indicates that the resulting parallels between the two dynamic outcomes as discovered in the two analyses are strong.

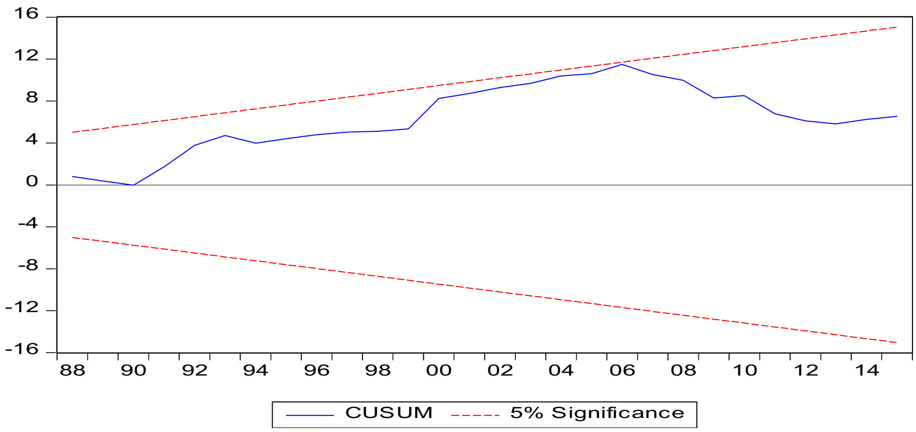

Fig. 1 CUSUM

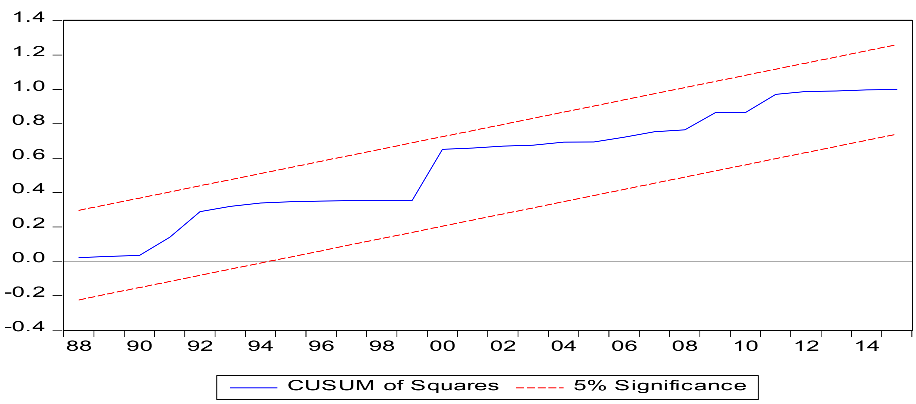

Fig. 2 CUSUM of squares. The straight lines represent critical bounds at 5% significance level

4.2 ARDL results and discussion

The long-run dynamic findings from the ARDL estimation are presented in Table 6. The data in this table established that financial development has a considerable beneficial effect on the possibilities for economic growth in France. Additionally, the study notes that a 1% point improvement in financial development in France results in a 0.02 percent boost in economic growth. These results show that as financial development is improving, it gives confidence to the investors to channel their funds into the economy thereby increasing the level of economic activity. Similar findings have been made regarding electricity use and economic growth. Moreover, this study also establishes that a 1% increase in electricity consumption in France results in a 0.27 percent rise in economic growth. The positive effect of electricity consumption on economic growth can be explained from the fact that every production requires energy consumption, particularly electricity consumption. Machinery and production plants require electricity to be in operation. Labour needs electricity to be able to work properly. Most production process cannot be completed without electricity consumption. As more electricity is consumed, it translates into increase in output of the firms. This finding contrasts with the findings of Karanfil and Li (2015) and Wolde-Rufael and Menyah (2010), who concluded that increasing electricity usage has a negligible effect on advanced economies'

Table 7 Chow forecast test

Forecast length: 2001 to 2015		Prob
F-statistic	3.6025	0.3212
Log-likelihood ratio	75.6132	0.0000

GDP (French inclusive). Our result also affirms the recent study by Apinran et al. (2022) who found electric power consumption to have promoted growth of Nigerian economy.

On the other hand, we observe that a 1% increase in physical capital enhances economic growth by 0.18 percent in France. This relationship is statistically significant at 1% level. The rationale for this relationship is consequent upon the fact that production process requires capita. As more capital is put into a business, more output would be realised from the business. Additionally, it was determined that French exports had a favourable and considerable effect on the country's economic growth. As a result of this link, a 1% rise in exports has a significant effect on the country's economic growth of 0.15 percent. This finding is less than the contribution of electricity consumption, which is 0.27 percent, implying that electricity consumption in France contributes more to the country's economic growth than any other variable considered in this study. Similarly, this analysis reveals a favourable and statistically significant link between imports and economic growth in France. According to the study's findings, a 1% increase in imports results in a 0.18 percent rise in French economic growth. Trade openness has a positive effect on economic growth and is statistically significant at the 1% level. This is because, as a country is involved in trade with other country, GDP will rise, which consequently promote economic growth. This is finding is consistent with Iorember et al. (2022) who argued that international trade has promoted the growth of the African OPEC member countries.

Table 6 summarises the results of the short-run analysis's estimation. These results revealed a favourable and significant association between France' electricity consumption and the country's economic growth potential. To demonstrate this, Table 6 shows that all the explanatory variables have a positive relationship with economic growth but the relationship between financial development proxy and economic growth was not statistically significant. The plausible reason was that, the financial system of France, particularly the credit to private sector is not yet developed to stimulate economic growth in the short run. Furthermore, the error correction term (ECM) is negative and statistically significant, with the exports, imports, and trade models estimated to have equilibrium adjustment coefficients of − 0.3686, − 0.5306, and − 0.4395, respectively, implying that short-run deviations from long-run equilibrium would be corrected at a rate of 36.86 percent, 53.06 percent, and 43.95 percent. These rates of adjustments indicate that the French economy benefits from some rapid adjustment/recovery processes or that it can recover from shocks more quickly. Additionally, as a robustness check, the study performed critical diagnostic tests to establish the validity of the ECM conclusion. As a result of this diagnostic test, the study determined that the error terms in the short-run model are normally distributed in all empirical models examined. Post-estimation diagnostics, on the other hand, demonstrate the absence of heteroskedasticity, serial

Table 8 VECM Granger causality results

Dependent variable	Type of causality					
	Short run					Long run
	$\sum \Delta \ln Y_{t-1}$	$\sum \Delta \ln EC_{t-1}$	$\sum \Delta \ln F_{t-1}$	$\sum \Delta \ln K_{t-1}$	$\sum \Delta \ln TO_{t-1}$	$\sum \Delta \ln TO_{t-1}$
$\Delta \ln Y_t$	–	7.3639*** [0.0024]	0.8278 [0.4464]	4.4349** [0.0202]	16.2868* [0.0000]	− 0.1631* [− 4.4861]
$\Delta \ln EC_t$	0.7126 [0.4984]	–	0.1330 [0.8419]	0.0207 [0.9795]	0.4322 [0.6530]	− 0.5961 [− 4.5928]
$\Delta \ln F_t$	2.5007*** [0.0909]	0.5639 [0.5749]	–	0.0633 [0.9388]	2.0707 [0.1433]	− 0.8204* [− 3.2507]
$\Delta \ln K_t$	10.3237* [0.0004]	0.8177 [0.4510]	0.1896 [0.8283]	–	0.8246 [0.4481]	− 0.2657* [− 3.3544]
$\Delta \ln TO_t$	16.2790* [0.0000]	1.4137 [0.2585]	2.0118 [0.1510]	0.3139 [0.7328]	–	–
	$\sum \Delta \ln Y_{t-1}$	$\sum \Delta \ln EC_{t-1}$	$\sum \Delta \ln F_{t-1}$	$\sum \Delta \ln K_{t-1}$	$\sum \Delta \ln EX_{t-1}$	ECT_{t-1}
$\Delta \ln Y_t$	–	4.1745** [0.0251]	1.1672 [0.3250]	17.5632* [0.0000]	10.7514* [0.0003]	− 0.3347*** [− 1.9763]
$\Delta \ln EC_t$	1.6781* [0.0000]	–	0.0934 [0.9111]	0.2128 [0.8095]	0.1472 [0.8637]	− 0.4838** [− 2.4603]
$\Delta \ln F_t$	0.1297 [0.8686]	0.5753 [0.5686]	–	0.0074 [0.9926]	0.2079 [0.8134]	− 1.0004* [− 3.9696]
$\Delta \ln K_t$	27.4559* [0.0000]	1.5326 [0.2324]	0.0363 [0.9648]	–	0.6268 [0.5411]	− 0.2917** [− 2.7502]
$\Delta \ln EX_t$	12.2242* [0.0001]	1.2976 [0.2876]	0.6280 [0.5403]	0.9417 [0.4008]	–	–
	$\sum \Delta \ln Y_{t-1}$	$\sum \Delta \ln EC_{t-1}$	$\sum \Delta \ln F_{t-1}$	$\sum \Delta \ln K_{t-1}$	$\sum \Delta \ln IM_{t-1}$	ECT_{t-1}
$\Delta \ln Y_t$	–	5.0905** [0.0123]	4.5044** [0.0192]	3.9775** [0.0290]	15.8681* [0.0000]	− 0.2305*** [− 1.8153]
$\Delta \ln EC_t$	1.0110 [0.3759]	–	0.3736 [0.5914]	0.0928 [0.9116]	0.5965 [0.5571]	− 0.5087* [− 4.2218]
$\Delta \ln F_t$	7.7339** [0.0348]	0.1253 [0.8826]	–	0.7382 [0.4865]	2.0005 [0.1529]	− 0.6617* [− 3.0982]
$\Delta \ln K_t$	2.5232*** [0.0971]	1.1841 [0.3199]	1.9641 [0.1579]	–	1.9382 [0.1616]	− 0.2164** [− 2.7020]
$\Delta \ln IM_t$	9.3251* [0.0007]	0.6030 [0.5530]	16.2080* [0.0000]	7.0109* [0.0031]	–	–

*, ** and *** indicate the level of significance at 1%, 5%, and 10%, respectively

correlation, and the ARCH problem. Additionally, the Ramsey reset test result suggested that the functional form of the short-run models was properly described.

In this study, we also examine the validity or otherwise of the long- and short-run stability of the exports model's parameters. To ensure the accuracy of this check, Brown et al. (1975) suggest using the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMsq). The CUSUM and CUSUMsq for the overall model are shown in Figs. 1 and 2.[6] These figures are intended to demonstrate the efficacy of the respective models and the robustness of the findings in this investigation. We see from the results of this empirical exercise that the plots of the CUSUM and CUSUM squares charts are

[6] Note that the CUSUM and CUSUM squares diagrams presented are for the baseline model where trade openness is applied. The CUSUM and CUSUM squares diagrams for where exports and import variables are used will be made available on reasonable request because of space.

inside the upper and lower critical lines at 5% level of significance. This implies that the models used for this study are stable.

To further validate the CUSUM and CUSUMsq findings regarding the parameter's stability, the Chow breakpoint test was used. As illustrated in Table 7, this test confirms the absence of a significant break point that distorts the estimated model across the specified duration. This demonstrates that our estimated model is quite well fitted.

4.3 The VECM Granger causality analysis

The VECM Granger causality test is used to determine the direction of the causal relationship between the variables in this study. Establishing the direction of the causal relationship between the various variables will allow for the possibility of answering the research questions presented previously in this study. Additionally, the results of this test may serve as a guide for French economic policymakers, particularly in the key areas examined in this study.

Table 8 summarises the findings of the VECM Granger causality test. The table illustrates the long-run and short-run dynamics of causality. In the long run, this study proved bidirectional causality between France's economic development and power usage. This indicates that France's economic growth is a result of the country's adequate and efficient electricity consumption. As a result, any attempt to curb French electricity consumption is equal to interfering with the country's economic growth trajectory. A similar pattern was observed in relation to France's capital formation prospects and economic development. This result is consistent with Rafindadi and Ozturk (2016) and Usman (2022).

Unlike prior findings, we uncover a feedback effect in the link between French electricity use and capital. Capital and financial development developed in a similar manner. On the other hand, it was discovered that the relationship between the level of financial growth obtained in France and the country's electricity usage is bidirectional. Surprisingly, this analysis revealed that economic growth Granger causes financial development, and vice versa. Additionally, we observe unidirectional causality between exports, imports, and trade and economic growth. In the case of France, electricity consumption, financial development, and capital are Granger-causes of exports, imports, and trade openness. These findings imply that the inextricable link between French electricity energy and the country's mantra of energy security constitutes the fundamental cause of all facets of development in the country. Thus, implying that electricity consumption in France is not simply a driver of growth but also the country's heartbeat.

The VECM Granger causality results reported in Table 8 reveals that the relationship between economic growth and electricity consumption in France is bidirectional in the short run. Through the feedback effect, the short-run result also reveals the existence of a relationship between capital and economic growth. Similarly, exports and economic growth are causally related in a bidirectional manner, but financial development and capital accumulation promote imports. On the other side, between financial development and economic progress, we identified a feedback effect. We also discover trade openness to be the Granger-cause of economic growth. The opposite of this also true.

5 Conclusion and policy implications

Recent development economics literature appears to accentuate an essential link between economic prosperity and efficient energy supply and consumption, among other factors. According to the argument, much of today's prosperity is based on secure and reliable energy access/use and without the essential energy infrastructure, modern industry comes to a halt. France is a case in point of a country having a substantial energy infrastructure. France has a very low carbon electricity mix due to its vast nuclear fleet, the second largest in the world after the United States. Despite its robust and efficient energy production and consumption, however, France's economic growth has been sluggish in recent years. This study examines whether electricity consumption is consistent with the advanced economy of France's economic growth potential. The study's specific objective is to determine why the French economy remains 'poor' despite the presence of efficient electricity energy in the country, and what impact this development will have on economic growth and other energy policy concerns in France. To complete this study, time series data from 1961 to 2015 were employed.

Following the study's straightforward methodology, dynamic results from the ARDL bounds testing technique for cointegration demonstrated that, in France, both financial development and electricity consumption stimulates economic growth in the long run but the short-run effect of financial development is insignificant. When they work tandemly, trade openness and capital exert strong significant positive effect on French economic growth. Additionally, this study sheds light on the feedback effect between economic growth and energy use. Similar conclusions about capital and economic growth have been made.

There is a bidirectional causal relationship between financial development, capital accumulation, and electricity usage. The Granger causality analysis confirmed previous findings that electricity usage has a considerable causal effect on France's economic growth. Additionally, the analysis indicated that exports, imports, and trade openness all contribute to economic growth in France. In terms of electricity consumption, financial development, and capital, the study debunks the myth that power use is incompatible with French economic growth. This development is backed by the Granger causality test and corroborated by the dynamic ARDL test findings. The study demonstrated how a 1% increase in financial development, electricity consumption, capital, exports, and imports results in a 0.02 percent, 0.27 percent, 0.18 percent, 0.15 percent, and 0.18 percent increase in French economic growth, respectively.

In line with the supporting evidence in this study, it is valid to argue that neither electricity nor the efficient electricity supply in France has ceased to serve as a catalyst for economic growth (considering that a 1% increase in electricity consumption in France is associated with a 0.27% increase in the country's GDP—a value higher than all other variables considered in this study). It is sufficient to argue from the outcomes of this study that it may be a lack of entrepreneurial and technological capacity in France that prevents the utilisation of existing sufficient and efficient electricity energy. That is to say, the horizon of France's productive electricity market and energy marketing system appears to be doomed by an incapacity to generate strategic innovation and synergies for directing power consumption to an infinite number of and diversified economic functions (all things being equal). This could occur, in particular, if France's entrepreneurial development policies are ineffectual or unsuccessful. As a result, this issue has the potential to obstruct the system's ability to explore new avenues for directing the economic use of power, thereby generating a forgone alternative to what could have otherwise increased national output. The following argument establishes the intuition that France has a high cost of doing business, which may be exacerbated by the country's high tax rate, thereby dwarfing, and creating an additional loophole in the direction of how electricity energy in France could be put to productive use.

With regard to why the French economy grows slowly despite the presence of efficient and effective electricity energy, this study believes that it is the fault of inefficient, chaotic, or conflicting economic policy arrangements that allowed responsive internal factors to combine and impair the country's economic growth prospects, thereby limiting the use of electricity for productive industrial purposes. These characteristics include France's macroeconomic stability and the effectiveness with which policy actions are formulated and guided to mitigate anticipated economic aberrations. For example, France has been continuously impacted by economic shocks such as the financial crisis and other domestic economic pressures. Lin and Liu (2016) showed that during economic depressions, the concentration of electricity energy consumption by heavy industrial outlets is often low. This will amplify the effects of low energy use on a country's economic growth potential. With this declining tendency continuing, the relative success of manufacturing industries will exacerbate inventory investment variations, resulting in a severe decline in productivity. This issue will impede efficient and effective energy use, ultimately harming a country's economic growth prospects.

The policy implications of this study for the France's future energy consumption and economic growth prospects relate to the creation of an environment conducive to entrepreneurial activity. This reflects a greater emphasis on power use in sensitive projects that can have a substantial impact on France's economic growth. Additionally, policymakers in France should examine how effectively electricity supply and consumption factors are exploited; are the costs associated with sustaining the country's research and development effective at generating a high level of applicable innovation and creativity in dealing with the country's energy system and its relationship to entrepreneurial development and economic growth? How is France's research and development system capable of enviably developing technology and science capable of allowing electricity energy to be used indefinitely? How quickly do French institutions expand to handle increased energy consumption? Apart from that, it is critical to analyse the soundness of capital accumulation and the speed with which it could expand to generate more value in France. Similarly, can the country's financial system convert capital into important channels for entrepreneurial productivity? Is the financial system sophisticated enough to channel funds in such a way that entrepreneurial activity thrives? Thus, it became critical for French energy policymakers to rethink their strategy in order to create additional opportunities for the country to use electricity indefinitely. This can be accomplished through intensive energy marketing strategies and the establishment of high-energy manufacturing and entrepreneurial enterprises that are sensitive to economic growth. To accomplish the aforementioned and reverse the deteriorating trend, this study advocates for channelling the country's positive financial development gains into the provision of productive loans to intending entrepreneurs who can at the very least put the country's enviable electricity energy to productive use.

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Author contributions
AAR: conceptualisation, formal analysis, investigation, data curation, writing—original draft, writing–review and editing. IBA: writing—original draft, writing—review and editing validation, visualisation. OU: writing—original draft, writing—review and editing, methodology, visualisaation. All authors read and approved the final manuscript.

Authors' information
Abdulkadir Abdulrashid Rafindadi is a Professor of Finance and Energy Economics at Usmanu Danfodiyo University, Sokoto, Nigeria. He has published several articles in top-tier journals in the field of Energy and financial economics. Isah Buhari Aliyu is currently a PhD student at Business School, University of Huddersfield, UK. Ojonugwa Usman holds a PhD in Economics from Eastern Mediterranean University, North Cyprus. He is currently an Assistant Professor, Department of Economics, Istanbul Ticaret University, Istanbul, Turkey.

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Declarations

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