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# Natural gas consumption and economic growth in France: Evidence for the role of exports, capital and labor

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# Natural gas consumption and economic growth in France:
# Evidence for the role of exports, capital and labor

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**Abstract:** The present study investigates the relationship between natural gas consumption and economic growth using Cobb-Douglas production function by incorporating exports, capital and labor as additional factors of production. We apply the ARDL bounds testing approach to test the existence of long run relationship between the series. The VECM Granger approach is implemented to detect the direction of causal relation between the variables. Our results show that variables are cointegrated for long run relationship. The results also indicate that natural gas consumption, exports, capital and labor are contributing factors to domestic production and hence economic growth in case of France. The causality analysis indicates that feedback hypothesis is validated between gas consumption and economic growth which implies that adoption of energy conservation policies should be discouraged. The bidirectional causality is also found between exports and economic growth, gas consumption and exports, capital and energy consumption, exports and capital. This study opens up new direction for policy makers to formulate a comprehensive energy policy to sustain economic growth for long span of time in case of France.

**Keywords:** Gas Consumption; Economic Growth; Exports; Capital; Labor; France.

## 1. Introduction

Natural gas, a vital energy resource, is increasingly being used as an essential input for many industries around the world. EIA [1] reports that world natural gas consumption as a percentage of total energy consumption has increased to 23% in 2007 from 21% in 1990. Total natural gas consumption is expected to grow at 18% annually between 2007 and 2035. Natural gas is a kind of fossil fuel that generates relatively less carbon dioxide emissions ($CO_2$) than other fossil fuels. Therefore, it would be efficient to optimize the use of natural gas by industries and households to meet the Kyoto target in reducing $CO_2$ emissions. With this objective, many countries are exploring the options for better use of natural gas as an alternative energy source [2]. In fact, natural gas is now considered as an attractive option because of its efficiency, better operational flexibility, reduced $CO_2$ emissions and lower capital costs.

France, the second largest economy in Europe, has very little domestic natural gas production. However, its natural gas consumption has been continuously increasing by the imports from various countries such as the Netherlands, Norway and Russia [3]. For example, the gas consumption in 2001 was 42 billion cubic meters. It has increased to 45 billion cubic meters in 2004 and nearly 50 billion cubic meters in 2010 [4]. In 2010, almost 98.5% gas consumption was met by imports [5].

Against this backdrop, it is vital for policy makers of France to understand the direction, strength and stability of the relationship between natural gas consumption and economic growth in order to design and execute proper energy policies. This is because there are four competing hypothesis as discussed in the existing literature [6]. For example, a reduction of gas consumption will lead to a fall in economic growth if causality runs from natural gas consumption to economic growth or bidirectional causality exists between both variables. If economic growth Granger causes natural gas consumption or neutral effect is found between both variables then reduction in natural gas supply will have little or no impact on economic growth. Though extensive empirical studies are found in the literature on the relationship between output growth and energy consumption, empirical studies on natural gas consumption and economic growth is limited. Moreover, there is a clear lack of consensus among the researchers. Apart from country specific factors, the main reason for the lack of consensus is that most of these studies used bivariate framework to test Granger causality. This results in biased and inconsistent estimates due to the omission of relevant variables that affect economic growth and energy/ natural gas consumption nexus. Therefore, inclusion of some other variables such as capital, labor, exports etc. in a multivariate framework will provide better and reliable results to analyze the relationship between economic growth and energy/natural gas consumption. That is why some recent studies on Granger causality have started to examine this relationship between energy/gas consumption and economic growth including the relevant variables such as capital, labor, employment, energy prices, exports, pollution emissions or urbanization [7–10]. Our current research will be a new addition to this effort in case of France by incorporating capital, exports and labor in production function.

Lean and Smyth [8] correctly identified some problems of using the bivariate framework in analyzing the relationship between energy and GDP. They argued that energy is not the only input to spur aggregate output. Actual output growth depends on the combination of inputs used, and the degree to which energy, capital and labor act as complements. Referring Lütkepohl [11], they also note that omission of relevant variables makes the estimates biased and inconsistent; in addition, bivariate system can yield no causality from neglected variables. For example, most of the Granger causality studies for Malaysia that used bivariate framework to analyze energy-GDP nexus have failed to find evidence of long-run causality. However, inclusion of extra variables provides more information that affect output growth. For a number of African countries, Wolde-Rufael [12] found a changed direction of causality after the inclusion of capital and labor.

Given the methodological problems of most of the studies in this area as described above, the importance of further studies, using appropriate framework including other important variables, on the causal relationship between gas/energy consumption and economic growth still exists. We therefore take care of those limitations, and adopt a multivariate approach using Cobb-Douglas production function by incorporating exports, capital and labor as additional factors of production in case of France. The reason for inclusion of exports is that exports seem to be a very important variable, and exports can affect both economic growth and hence natural gas consumption. Moreover, exports increase total factor productivity through impact on economies of scale, production capacity and improve workers and managerial skills. Exports facilitates for a better utilization of resources and do not discriminate the domestic market [13–14]. We thus intend to investigate the existence of long run relationship between natural gas consumption and economic growth in France considering three additional variables in production.

The reason for selecting France for this case study is that there is, to the best of our knowledge, very limited study that extensively and exclusively examines energy–GDP or gas–GDP nexus for France. Wolde-Rufael and Menyah [15] examined the relationship between nuclear energy consumption and economic growth of nine developed countries where France is included. The study of Lee and Chiu [16] on nuclear energy consumption, oil prices, and economic growth also includes France among other 5 countries. Apergis and Payne [2] include France in a panel of 67 countries. Recently, Amiri and Zibaei [17] conducted a study on France using geo-statistical models to examine the Granger causality between energy use and economic growth, but this study suffers from the omitted variable bias as the authors consider two variables only: GDP growth and oil consumption. We find no study for France that extensively examined the causality between natural gas consumption and economic growth. Thus our current study is unique, and will be a significant contribution for the policy makers of France in particular and other countries in general.

The rest of the paper is organized as follows: section 2 reviews the existing literature; section 3 states data, methodological framework and modeling; section 4 indicates and discusses the empirical results; and last section concludes the paper with policy implications.

## 2. Literature Review

Energy–growth nexus or natural gas consumption-growth nexus can be described by the following four hypotheses: growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis. According to the growth hypothesis energy/gas use is critical for economic growth. So a reduction in energy/gas use lowers GDP implying that the economy is energy/gas dependent. The conservation hypothesis regards that there exists a unidirectional causality from economic growth to energy/gas use. Therefore, economic growth may not be much affected by any policy to reduce energy/gas consumption. The feedback hypothesis assumes that there exists a bi-directional causality implying that energy/gas consumption and economic growth affect each other. Neutrality hypothesis states that lower energy/gas consumption does not affect economic growth, and vice versa [18].

For example; Yu and Choi [19] found neutral effect between natural gas consumption and economic growth in case of USA and Poland, but unidirectional relationship from economic growth to natural gas consumption for UK. Yang [20] also conducted a study on Taiwan covering data period 1954–1997, and found unidirectional Granger causality from natural gas consumption to economic growth, but no cointegration between two variables. Aqeel and Butt [21] and Siddiqui [22] explored causal relationships between real GDP and natural gas consumption for Pakistan. The first study used data from 1955 to 1996, and the second study used data from 1970 to 2003. Lee and Chang [23] explored the importance of structural breaks using data of 1965–2003 in case of Taiwan and found that Taiwan natural gas consumption Granger causes economic growth. This implies that a decrease in the volume of natural gas consumption will slow economic growth in case of Taiwan. However, with conventional vector-error correction model, the study does not find long-run equilibrium. Zamani [24] used the vector error correction model for empirical purpose in case of Iranian economy over the period of 1967–2003. The author found the bidirectional casual relationship between natural gas consumption and economic growth in long run. Ewing et al. [25] employed Generalized Forecast Error Variance Decomposition method for the USA economy and found unidirectional causality running from natural gas consumption to economic growth.

Sari et al. [26] employed Johansen and Juselius [27] approach to identify cointegration relationship between natural gas consumption and economic growth. This cointegration approach is considered more powerful than the Engle and Granger [28] test for a country specific analysis. Taking monthly data for the period of 2001:1–2005:6, Sari et al. [26] applied the ARDL bounds testing approach which can detect cointegration even for small samples. Their findings reveal no significant impact of industrial production on natural gas consumption in long run. Reynolds and Kolodziej [29] conducted a study on the former Soviet Union to explore cointegration, and use Engle and Granger [28] causality test. They found no causal relationship between natural gas consumption and economic growth mainly because Soviet Union has stable level of natural gas consumption due to low variable costs of production. Hu and Lin [30] also conducted a study on Taiwan using shorter period of quarterly data: 1982:1–2006:4. They also considered a structural break in the analysis, and use threshold vector-error correction model with two regimes. Their findings confirmed that, with faster adjustments of natural gas consumption than GDP, long-run equilibrium exists. Amadeh et al. [31] applied Johansen cointegration approach and reported that variables are cointegrated for long run and causality analysis reveals that economic growth Granger causes natural gas consumption over the period of 1973–2003.

Işik [32] found a positive impact of natural gas consumption on economic growth in short run, but a negative impact on the growth in long run for Turkey while an Auto-Regressive Distributive Lag (ARDL) model is applied using data of 1977–2008. Apergis and Payne [2] applied the panel vector error correction model for 67 countries which revealed the bidirectional causality between natural gas consumption and economic growth in both short and long runs. The same results were also observed by Lim and Yoo [33] in Korea where multivariate vector error correction models are applied using quarterly data of 1991–2008. Recently, Shahbaz et al. [34] used production function to reinvestigate the relationship between natural gas consumption and economic growth in case of Pakistan. They confirmed the presence of cointegration between the variables and found that natural gas consumption contributes economic growth. Their analysis also exposed that exports play their role in affecting economic growth and natural gas consumption.

Furthermore, Fatai et al. [35] used data from 1960 to1999 and employed ARDL, Johnson’s Maximum Likelihood (JML) and Toda and Yamamoto causality test methods. Zahid [36] used Toda and Yamamoto causality test method considering sample period of 1971–2003, and Kum et al. [37] employed Bootstrapping Granger Causality test taking sample period of 1970–2008.

Fatai et al. [35] reported no cointegration between natural gas consumption and economic growth for New Zealand but found cointegration for Australia while neutral effect is validated between both variables. Similarly Zahid [36] found no cointegration for Bangladesh, India, Nepal and Sri Lanka, but cointegration for Pakistan. The author reported that economic growth was Granger caused by natural gas consumption in case of Bangladesh. Kum et al. [37] found bidirectional causality for France, Germany and the USA, and unidirectional causality from gas consumption to economic growth for Italy and unidirectional causality for economic growth to natural gas consumption in case of the UK.

The above discussion clearly indicates that there is a lack of clear consensus on the relationship between natural gas consumption and economic growth not only in the existing literature but also in case of France. This is due to methodological differences, different data periods, country heterogeneity in climate, and different stages of economic growth and energy (gas) use patterns. Therefore, country-specific studies covering current period of data, especially when global financial crisis and the recent development in climate change agenda have drastically changed the fuel mix policy, are very vital. This study is a humble effort to fill up the gap in the existing literature.

## 3. Data, Methodological Framework and Modeling

### *3.1. Data and model specification*

The present study aims to investigate the relationship between natural gas consumption and economic growth by incorporating capital, exports and labor in production function. We follow the methodological framework of Moroney [38], Lee [39], Narayan and Smyth [40], Apergis and

Payne [2], and Shahbaz et al. [34], to construct the production function. The general functional form of the model is as follows:

$$Y_t = f\left(G_t, E_t, K_t, L_t\right) \tag{1}$$

where Y is real GDP per capita in constant 2000 US dollars, G is the natural gas consumption per capita defined by dry natural gas in billions of cubic feet, E is real exports per capita in constant 2000 US dollars, K is real gross fixed capital formation in constant 2000 US dollars, and L is employed labor per capita[1]. Annual data from 1970 to 2010 have been obtained from the *World Bank Development Indicators* (CD-ROM, 2012) and the *Energy Information Administration*. We have transformed all the series into logarithmic form. The logarithmic linear specification of Eq. (1) is as follows:

$$\ln Y_t = \alpha_0 + \alpha_1 . \ln G_t + \alpha_2 . \ln E_t + \alpha_3 . \ln K_t + \alpha_4 . \ln L_t + \varepsilon_t \tag{2}$$

$\alpha_1$, $\alpha_2$, $\alpha_3$, and $\alpha_4$ indicate the elasticities of natural log of natural gas consumption per capita, natural log of real exports per capita, natural log of real gross fixed capital formation per capita and natural log of employed labor per capita, respectively. $\varepsilon_t$ is the residual term assumed to be normally distributed. The descriptive statistics and the correlation matrix of different variables in case of France are given in Table 1.

The results reported in Table-1 show that all the series have normal distribution confirmed by Statistics of Jarque-Bera test. We find that positive correlation is found between natural gas

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[1] We used population series to convert all the series into per capita following Shahbaz and Lean [41].

consumption and economic growth, exports and economic growth, capital (labor) and economic growth. Exports and capital are positively correlated with natural gas consumption but correlation between labor and natural gas consumption is negative. The correlation between capital (labor) and exports is negative. Capital and labor are negatively correlated.

**Table 1**
Descriptive statistics and correlation matrix.

| **Variables** | $\ln Y_t$ | $\ln G_t$ | $\ln E_t$ | $\ln K_t$ | $\ln L_t$ |
|---|---|---|---|---|---|
| Mean | 9.8727 | 6.1056 | 8.3684 | 8.2419 | 4.1685 |
| Median | 9.9214 | 6.1175 | 8.3728 | 8.2166 | 4.1762 |
| Maximum | 10.1503 | 6.4771 | 8.8305 | 8.5944 | 4.1910 |
| Minimum | 9.4390 | 5.1840 | 7.5911 | 7.9297 | 4.1321 |
| Std. Dev. | 0.2030 | 0.2998 | 0.3441 | 0.1847 | 0.0192 |
| Skewness | -0.3783 | -1.1207 | -0.4227 | 0.3971 | -0.8563 |
| Kurtosis | 2.0867 | 4.2118 | 2.4084 | 1.9527 | 2.2501 |
| $\ln Y_t$ | 1.0000 | | | | |
| $\ln G_t$ | 0.4891 | 1.0000 | | | |
| $\ln E_t$ | 0.7392 | 0.2606 | 1.0000 | | |
| $\ln K_t$ | 0.7823 | 0.3024 | 0.4751 | 1.0000 | |
| $\ln L_t$ | 0.0464 | -0.1254 | 0.0841 | -0.1596 | 1.0000 |

### *3.2. ARDL bounds testing approach*

To study the cointegration approach, we employ the ARDL bounds testing approach developed by Pesaran et al. [42] to explore the existence of long-run equilibrium between the variables. This approach has several advantages. It yields consistent long-run estimators even when the right hand side variables are endogenous [43]. It also solves the endogeneity problems and the inability to test hypotheses on the estimated coefficients in the long-run associated with the Engle-Granger method [28]. By using the appropriate order, it is possible to simultaneously correct the serial correlation in residuals and the problem of endogenous regressors [44]. This approach is applied irrespective of whether the variables are purely I(0) or I(1), unlike other widely used cointegration techniques. It is also found that the small sample properties of the bounds testing approach are far superior to that of multivariate cointegration [45]. Moreover, a dynamic unrestricted error correction model (DUECM) can be derived through a simple linear transformation. The DUECM integrates the short-run dynamics with the long-run equilibrium without losing any long-run information. At this level, the DUECM of Eq. (2), estimated with natural log of real GDP per capita as the dependent variable, is specified as follows:

$$\begin{aligned} \Delta \ln Y_t = \beta_0 &+ \sum_{i=1}^{p} \beta_1.\Delta \ln Y_{t-i} + \sum_{j=0}^{q} \beta_2.\Delta \ln G_{t-j} + \sum_{k=0}^{r} \beta_3.\Delta \ln E_{t-k} + \sum_{l=0}^{s} \beta_4.\Delta K_{t-l} + \sum_{m=0}^{w} \beta_5.\Delta l_{t-m} \\ &+ \beta_6.\ln Y_{t-1} + \beta_7.\ln G_{t-1} + \beta_8.\ln E_{t-1} + \beta_9.K_{t-1} + \beta_{10}.L_{t-1} + \mu_t \end{aligned} \qquad (3)$$

where Δ is the first difference operator and $\mu_t$ is the error term. The optimal lag structure of the first difference regression is selected based on Akaike Information Criteria (AIC). The lags is induced when noise in the error term. Pesaran et al. [42] suggested F-test for joint significance of the coefficients of the lagged level of the variables. Initially, a joint significance test, that implies no cointegration hypothesis ($H_0 : \beta_i = 0$; $\forall$ i= 6, 7, 8, 9, 10) against the alternative hypothesis ($H_1 : \beta_i \neq 0$; $\forall$ i= 6, 7, 8, 9, 10), should be performed for Eq. (3). The bounds testing approach to cointegration requires carrying out the F-test on the selected ARDL models including appropriate lag lengths of selection criterion such as AIC.

At the second stage, it is also possible to perform for the selected ARDL representation, a general error correction model (ECM) of Eq. (3) formulated as follows:

$$\Delta \ln Y_t = \phi_0 + \sum_{i=1}^{p} \theta_1.\Delta \ln Y_{t-i} + \sum_{j=0}^{q} \theta_2.\Delta \ln G_{t-j} + \sum_{k=0}^{r} \theta_3.\Delta \ln E_{t-k} + \sum_{l=0}^{s} \theta_4.\Delta K_{t-l} + \sum_{m=0}^{w} \theta_5.\Delta l_{t-m} + \lambda.ECT_{t-1} + \xi_t \quad (4)$$

where Δ is the first difference term; $\lambda$ is the error correction parameter, $ECT_{t-1}$ is the residuals that are obtained from the estimated cointegration model of Eq. (2), and $\xi_t$ is the disturbance term assumed to be uncorrelated with zero means. The ARDL bounds test of cointegration is complemented by Johansen and Juselius's [27] maximum likelihood to provide a sensitivity check on the results. A brief reminder of the Johansen and Juselius's [27] multivariate cointegration methodology is illustrated below:

$$X_t = A + \sum_{z=1}^{b} \Gamma_z . X_{t-z} + \eta_t \tag{5}$$

where $X_t = (\ln Y_t,\ \ln G_t,\ \ln E_t,\ \ln K_t,\ \ln L_t)$ represents a vector of endogenous I(1) variables, *A* is a vector of constant terms, $\Gamma$ represents coefficient matrix , *b* denotes the lag length, and $\eta_t$ is the residual matrix. All variables in Eq. (5) are considered to be potentially endogenous. The cointegrating rank can be found via the trace and the maximal eigen value tests. The lag length of the unrestricted vector autoregressive (VAR) structure in Eq. (5) is based on the AIC lag selection criterion.

### *3.3. Granger causality test*

A vector error correction model (VECM) is estimated to perform Granger-causality test [44]. This method is followed by the two steps of Engle and Granger [28] and employed to investigate the long-run and short-run dynamic causal relationships. The first step estimates the long-run parameters in Eq. (2) in order to obtain the residuals corresponding to the deviation from equilibrium. The second step estimates the parameters related to the short-run adjustment. The resulting equations are used in conjunction with Granger causality testing:

$$\begin{pmatrix} \Delta\ln Y_t \\ \Delta\ln G_t \\ \Delta\ln E_t \\ \Delta\ln K_t \\ \Delta\ln L_t \end{pmatrix} = \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \end{pmatrix} + \sum_{c=1}^{d} \begin{pmatrix} \theta_{1,1,c} & \theta_{1,2,c} & \theta_{1,3,c} & \theta_{1,4,c} & \theta_{1,5,c} \\ \theta_{2,1,c} & \theta_{2,2,c} & \theta_{2,3,c} & \theta_{2,4,c} & \theta_{2,5,c} \\ \theta_{3,1,c} & \theta_{3,2,c} & \theta_{3,3,c} & \theta_{3,4,c} & \theta_{3,5,c} \\ \theta_{4,1,c} & \theta_{4,2,c} & \theta_{4,3,c} & \theta_{4,4,c} & \theta_{4,5,c} \\ \theta_{5,1,c} & \theta_{5,2,c} & \theta_{5,3,c} & \theta_{5,4,c} & \theta_{5,5,c} \end{pmatrix} . \begin{pmatrix} \Delta\ln Y_{t-c} \\ \Delta\ln G_{t-c} \\ \Delta\ln E_{t-c} \\ \Delta\ln K_{t-c} \\ \Delta\ln L_{t-c} \end{pmatrix} + \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{pmatrix} .ECT_{t-1} + \begin{pmatrix} \xi_{1,t} \\ \xi_{2,t} \\ \xi_{3,t} \\ \xi_{4,t} \\ \xi_{5,t} \end{pmatrix} \quad (6)$$

where $\phi_j$ (j=1,2,3,4,5) represents the fixed country effect; $c$ ($c = 1,\dots,d$) is the optimal lag length determined by the minimization of AIC criterion, $ECT_{t-1}$ is the estimated lagged error correction term derived from the long-run relationship presented in Eq. (2) and estimated via Eq. (6), $\lambda_j$ (j=1,2,3,4,5) is the adjustment coefficient, and $\xi_{j,t}$ (j=1,2,3,4,5) is the disturbance term assumed to be uncorrelated with zero means. Opposite to Eq. (4), all error-correction vectors in Eq. (6) are estimated with the same lag structure ($p = q = r = s = w = d$) that is determined in unrestricted VAR framework.

## 4. Empirical results

### *4.1. Unit root tests*

We applied two unit root tests such as Augmented-Dickey-Fuller (ADF) of Dickey and Fuller [46] and Phillips-Perron (PP) of Phillips and Perron [47] to test the unit root properties of the variables. The results are shown in Table 2 and we find that all series contain unit root problem at their levels but found to be stationary at 1st difference. Hence, we conclude that all variable are integrated at order 1, i.e. I(1).

**Table 2**
Unit root tests results.

| | *ADF unit root test* | | *PP unit root test* | |
|---|---|---|---|---|
| | *T-statistics* | *P-values* | *T-statistics* | *P-values* |
| *lnY* | -2.1324 (1) | 0.5123 | -2.0705 (3) | 0.5458 |
| Δ *lnY* | -4.2553 (1)* | 0.0091 | -4.8881 (3)* | 0.0020 |
| *lnG* | -3.0212 (6) | 0.1414 | -2.2457 (3) | 0.4544 |
| Δ *lnG* | -3.7329 (2)** | 0.0331 | -5.3948 (6)* | 0.0004 |
| *lnE* | -1.8582 (1) | 0.6567 | -1.5789 (3) | 0.7836 |
| Δ *lnE* | -4.5710 (1)* | 0.0041 | -5.7941 (6)* | 0.0001 |
| *lnK* | -3.1756 (2) | 0.1047 | -2.0996 (6) | 0.5302 |
| Δ *lnK* | -4.2630 (1)* | 0.0091 | 6.1040 (3)* | 0.0000 |
| *lnL* | 0.4383 (2) | 0.9988 | -0.7682 (3) | 0.9602 |
| Δ *lnL* | -5.8886 (1)* | 0.0001 | 5.3809 (6)* | 0.0006 |

Δ is the first difference term. ADF and PP examine the null hypothesis of non-stationary. * and ** represent significance at the 1 and 5% levels, respectively. (.) indicates lags for AFD and bandwidth for PP unit root tests, respectively.

### *4.2. ARDL cointegration method*

The first step in applying the ARDL bounds testing approach to cointegration is the selection of optimal lag length. The appropriate lag length of 2 is selected based on the minimization of AIC and it is sufficiently long for annual data i.e. 1970–2010 to capture the dynamic relationship of the ARDL model. AIC statistic is used because it has superior properties, particularly in small sample [48]. Overall, the ARDL model passed a number of diagnostic tests. The Jarque-Bera normality test ($\chi^2_{NORMAL}$) indicates that the residuals are normally distributed. The autoregressive conditional heteroskedasticity (ARCH, $\chi^2_{ARCH}$), white heteroscedasticity ($\chi^2_{WHITE}$) and Ramsey RESET ($\chi^2_{REMSEY}$) tests show that the ARDL model is free from ARCH problems and also from the general specification error (see Table 3). Finally, the Breusch-Godfrey LM test ($\chi^2_{SERIAL}$) cannot reject the null hypothesis of serial correlation up to second order, meaning that there is an absence of serial correction problem in the ARDL model.

Therefore, results of the ARDL bounds testing approach to cointegration together with the diagnostic tests are reported in Table 3. Fortunately, our calculated F-statistic is greater than upper critical bund at 5% level, provided by Narayan [45]. Therefore, the null hypothesis of no cointegration can be rejected, implying that a long-run equilibrium relationship exists between real GDP per capita, natural gas consumption per capita, real exports per capita, real capital per capita and labor in case of France.

**Table 3**
ARDL bounds testing analysis.

| *Bounds testing to cointegration* | | | *Diagnostic tests* | | | |
|---|---|---|---|---|---|---|
| *Estimated models* | *Optimal lag length* | *F-statistics* | $\chi^2_{NORMAL}$ | $\chi^2_{ARCH}$ | $\chi^2_{RESET}$ | $\chi^2_{SERIAL}$ |
| $F_Y\left(Y/G,E,K,L\right)$ | 2, 2, 2, 2, 1 | 7.1025** | 1.2609 | [1]: 0.9598 | [1]: 0.6149 | [2]: 4.1338; [3]: 1.9609 |
| $F_G\left(G/Y,E,K,L\right)$ | 2, 2, 1, 2, 2 | 8.0738* | 0.8946 | [2]: 0.1293 | [1]: 0.3701 | [1]: 0.8194; [2]: 0.5351 |
| $F_E\left(E/Y,G,K,L\right)$ | 2, 2, 2, 1, 1 | 7.2288** | 2.1601 | [1]: 0.0045 | [1]: 1.7402 | [1]: 2.1887; [2]: 3.4058 |
| $F_K\left(K/Y,G,E,L\right)$ | 2, 2, 2, 2, 1 | 8.1648* | 3.1248 | [1]: 1.4675 | [1]: 0.1680 | [1]: 0.1876; [2]: 0.4736 |
| $F_L\left(L/Y,G,E,K\right)$ | 2, 2, 2, 2, 2 | 8.8369* | 1.5305 | [1]: 0.7162 | [1]: 0.0749 | [1]: 0.1567; [2]: 3.3004 |

| Significant level | Critical values (T=41)# | |
|---|---|---|
| | Lower bounds $I(0)$ | Upper bounds $I(1)$ |
| 1% level | 6.053 | 7.458 |
| 5% level | 4.450 | 5.560 |
| 10% level | 3.740 | 4.780 |

$\chi^2_{NORMAL}$ is for normality test, $\chi^2_{ARCH}$ is for autoregressive conditional heteroscedasticity, $\chi^2_{WHITE}$ for white heteroscedasticity, $\chi^2_{RESET}$ is for Remsey RESET test, and $\chi^2_{SERIAL}$ is for LM serial correlation test. The asterisks * and ** denote significance at the 1 and 5 % levels, respectively. The optimal lag length is determined by AIC. [ ] is the order of diagnostic tests. #: Critical values are collected from Narayan [45].

Table 4 reports the long-and-short runs elasticities of each production factors. The finding indicates that natural gas consumption per capita is positively and significantly linked with economic growth. This result is consistent with Apergis and Payne [2] in case of 67 economies including France but contradict with Işik [32] in case of Turkey. Empirically, the results posit that a 1% increase in natural gas consumption per capita is linked with 0.154% increase in economic growth in long-run, and with 0.064% in short-run, both of which are significant at the 1% level, all else is the same. In addition, a 1% rise in real exports per capita is positively linked with economic growth by 0.197% in long-run and 0.116% in short-run by keeping other things constant, both of which are significant at 1% level. This empirical evidence is consistent with Shahbaz et al. [34]. On other hand, an increase in real capital per capita by 1% leads economic growth by 0.385% in long-run and 0.241% in short-run if other things remain the same, both of which are significant at 1% level. Finally, economic growth is also positively and significantly contributed by labor. A 1% increase in labor force will enhance economic growth by 0.191% in long run and 0.066% in short-run, all else is constant.

**Table 4**
Short- and long-runs results.

Dependent variable = $\ln Y_t$

| | *Long run analysis* | | | *Short run analysis* | | |
|---|---|---|---|---|---|---|
| Variables | Coefficient | T-Statistic | P-value | Coefficient | T-Statistic | P-value |
| Constant | -3.8348* | -3.6552 | 0.0009 | 0.0076* | 6.0524 | 0.0000 |
| $\ln G_t$ | 0.1536* | 3.3523 | 0.0020 | 0.0640* | 2.7967 | 0.0087 |
| $\ln E_t$ | 0.1970* | 4.3851 | 0.0001 | 0.1159* | 8.4247 | 0.0000 |
| $\ln K_t$ | 0.3850* | 9.5270 | 0.0000 | 0.2408* | 8.0823 | 0.0000 |
| $\ln L_t$ | 0.1905* | 7.6068 | 0.0000 | 0.0662** | 2.0714 | 0.0465 |
| $ECM_{t-1}$ | | | | -0.0949** | -2.1773 | 0.0369 |

*Diagnostic tests*

| Test | F-statistic | P-value |
|---|---|---|
| $\chi^2_{NORMAL}$ | 0.3826 | 0.8258 |
| $\chi^2_{ARCH}$ | 0.0519 | 0.8210 |
| $\chi^2_{REMSEY}$ | 0.7549 | 0.3915 |
| $\chi^2_{SERIAL}$ | 1.0103 | 0.3761 |
| $\chi^2_{WHITE}$ | 0.7097 | 0.7076 |

$R^2 = 0.8461$ F-statistic = 35.1929*** DW = 1.6540

* and ** indicate significance at the 1 and 5% levels of significance, respectively.

Shahbaz et al. [49] for Portugal, and Shahbaz and Dube [50] and Shahbaz et al. [34] for Pakistan reported that employment is also responsible to enhance economic growth. Our findings are broadly consistent with Moroney [38], Lee [39], Narayan and Smyth [40], Apergis and Payne [2], Işik [32], Kum et al. [37], Lim and Yoo [33], Shahbaz et al. [34] and Farhani et al. [51].

The lagged error term i.e. $ECM_{t-1}$ is having the expected negative sign and statistically significant at 5% level of significance. This confirms the established long-run relationship between the variables. The coefficient of lagged error term implies that deviations from short run to long-run equilibrium in current to future period are corrected by about 9.49% per year. The diagnostic tests indicate that the model passed the tests such as serial correlation, functional form, normality and heteroscedasticity. The high value of $R^2$ for ECM-ARDL model shows that the adjustment of the ARDL model is extremely good ($R^2 = 0.8461 \rightarrow 1$). The F-statistic which measures the joint significance of all regressors in the models is statistically significant at 1% level, and Durbin-Watson statistic for the model is approximately near to two (absence of errors autocorrelation).

### *4.3. Granger causality results*

After determining the presence of cointegration between real GDP per capita, natural gas consumption per capita, real exports per capita, real capital per capita and labor per capita, it is interesting to perform the Granger causality test to provide a clearer picture for policymakers to formulate economic policies and energy strategies by understanding the direction of causality. As the variables are cointegrated, we employed the Granger causality in the VECM framework to determine the direction of causality between the variables. The results of Granger causality are presented in Table 5. Since the variables are cointegrated, the direction of causality can be divided into short-and-long runs causation. The short-run causality is determined by the statistical significance of the partial F-statistics associated with the right hand side variables. The long-run causality is revealed by the statistical significance of the respective error correction terms using a t-test. Begin with the long-run causality, we find that the $ECT_{t-1}$ coefficients are statistically significant for all VECM equations.

In long run, we find that the relationship between natural gas consumption per capita and real GDP per capita is bidirectional in case of France. This is in line with Shahbaz et al. [49], but contrary to the findings of Chontanawat et al. [52], Narayan and Prasad [53] and Ciarreta et al. [54]. The bidirectional causal relationship is found between natural gas consumption and exports and the same inference is true for exports and economic growth. The feedback effect is found between capital and economic growth and the same conclusion is drawn for labor and economic growth. Exports Granger cause capital (labor) and the same is true from opposite side. Capital Granger causes natural gas consumption and natural gas consumption Granger causes exports. The relationship between labor and natural gas consumption is bidirectional.

In short run, economic growth is Granger cause of natural gas consumption and the same is true from opposite side. Natural gas consumption is Granger cause of exports. The feedback effect is found between capital and economic growth and the same inference is validated for capital and natural gas consumption. Labor Granger causes natural gas consumption, economic growth and exports but bidirectional causality is found between capital and labor.

**Table 5**
VECM Granger causality analysis.

| Dependent Variable | Short-run | | | | | Long-run | Joint short- and long-runs causality | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\Delta\ln Y_{t-1}$ | $\Delta\ln G_{t-1}$ | $\Delta\ln E_{t-1}$ | $\Delta\ln K_{t-1}$ | $\Delta\ln L_{t-1}$ | $ECT_{t-1}$ | $\Delta\ln Y_{t-1}, ECT_{t-1}$ | $\Delta\ln G_{t-1}, ECT_{t-1}$ | $\Delta\ln E_{t-1}, ECT_{t-1}$ | $\Delta\ln K_{t-1}, ECT_{t-1}$ | $\Delta\ln L_{t-1}, ECT_{t-1}$ |
| $\Delta\ln Y_{t-1}$ | # | 5.1816**<br>(0.0125) | 16.4425*<br>(0.0000) | 34.6798*<br>(0.0000) | 0.2826<br>(0.7560) | -0.2383*<br>[-2.6776] | # | 4.8944*<br>(0.0076) | 11.1783*<br>(0.0001) | 23.1212*<br>(0.0000) | 2.8775***<br>(0.0547) |
| $\Delta\ln G_{t-1}$ | 4.4949**<br>(0.0207) | # | 2.9099***<br>(0.0717) | 2.4089<br>(0.1090) | 3.0351***<br>(0.0647) | -0.7770*<br>[-5.1616] | 12.5613*<br>(0.0000) | # | 12.1982*<br>(0.0000) | 13.0613*<br>(0.0000) | 9.8772*<br>(0.0002) |
| $\Delta\ln E_{t-1}$ | 14.6867*<br>(0.0000) | 0.8373<br>(0.4438) | # | 1.1200<br>(0.3410) | 0.6914<br>(0.5095) | -0.5244*<br>[-2.6429] | 15.6407*<br>(0.0000) | 3.5645**<br>(0.0271) | # | 3.3929**<br>(0.0322) | 3.7167**<br>(0.0233) |
| $\Delta\ln K_{t-1}$ | 32.3409*<br>(0.0000) | 4.3184**<br>(0.0236) | 5.2656**<br>(0.0117) | # | 0.5519<br>(0.5822) | -0.2939*<br>[-5.7174] | 29.8490*<br>(0.0000) | 8.5891*<br>(0.0004) | 11.0569*<br>(0.0001) | # | 8.7243*<br>(0.0003) |
| $\Delta\ln L_{t-1}$ | 0.6607<br>(0.5246) | 0.2416<br>(0.7870) | 0.8741<br>(0.4287) | 3.5714**<br>(0.0420) | # | -0.0645*<br>[-3.4496] | 4.0606**<br>(0.0167) | 5.2012*<br>(0.0058) | 5.7375*<br>(0.0036) | 5.1737*<br>(0.0059) | # |

*, ** and *** indicate significance at 1, 5 and 10% levels, respectively. P-values are listed in parentheses and t-statistics are presented in brackets. With respect to Eq. (6), short-run causality is determined by the statistical significance of the partial F-statistics associated with the right hand side variables. Long-run causality is revealed by the statistical significance of the respective error correction terms using a t-test.

## 5. Conclusion and policy implications

We have investigated the relationship between natural gas consumption and economic growth by incorporating real exports, real gross fixed capital formation and labor in a multivariate framework in case of France over the period 1970–2010. We have applied the ARDL bunds testing cointegration approach for long run and stationary properties are tested by unit root tests. The direction of causality between the variables is investigated by applying the VECM Granger causality.

Our results validated the presence of cointegration between the variables for long run relationship. We find that natural gas consumption contributes to economic growth. Capital adds in economic growth. Exports stimulate economic growth. Similarly, labor is also a contributing factor to economic growth. The causality analysis exposes the bidirectional causality between natural gas consumption and economic growth. Exports Granger cause economic growth and then natural gas consumption and opposite reacts the same to exports.

The obtained results imply that reduction of natural gas consumption will decline economic growth and hence exports. Exports have positive impact on economic growth. If economic growth is declined, the demand for natural gas will also decline. Overall, we can say that natural gas conservation policies will adversely affect exports and economic growth. This suggests that French government should research, and expenditures in energy sector should increase to ensure consistent supply of natural gas consumption for sustainable economic growth. The consistent supply will enhance domestic production and hence exports which stimulate economic growth for long span of time.

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