

**Relationship between Natural Gas
Consumption and Economic Growth:
Evidence of the largest consumers of natural
gas countries**

VERSÃO FINAL APÓS DEFESA

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Resumo

Motivada pelos efeitos da utilização de energias não renováveis como é o caso do gás natural, esta dissertação pretende analisar o efeito do consumo de gás natural no crescimento económico. Neste trabalho são utilizadas técnicas de dados em painel que abrangem 16 países, sendo estes os maiores consumidores de gás natural, segundo a *Index Mundi*, com frequência anual e um horizonte temporal de 1995 até 2017. Devido às características dos dados, o modelo Autoregressive Distributed Lag (ARDL) provou ser o mais adequado para capturar a relação dinâmica em efeitos de curto e longo prazo. Os resultados obtidos indicam uma relação positiva entre consumo de gás natural e crescimento económico tanto a curto como a longo prazo.

Palavras-chave

Consumo de Gás Natural; Crescimento Económico; ARDL

Resumo Alargado

De modo a satisfazer as crescentes necessidades energéticas, pois a população mundial tem vindo a aumentar, e também de forma a satisfazer as necessidades ambientais, pois as alterações climáticas que é um tema de ordem atualmente, têm de ser alvo de combate, surge a necessidade de estudo do gás natural. A população mundial carece de energia para executar ações básicas no dia a dia de cada indivíduo, e essa utilização energética tem as suas implicações em termos ambientais e por isso tem de se adotar melhores métodos para diminuir estes impactos no ambiente. Assim sendo, o gás natural enquadra-se nesta transição energética, porque apesar de não ser uma fonte de energia renovável, é sem dúvida, a fonte de calor mais sustentável dentro das não-renováveis, isto é, dentro das fontes convencionais é a que menos emite dióxido de carbono para a atmosfera e os seus custos associados são reduzidos.

O gás natural desempenha um papel fundamental nesta transição energética com que o mundo se depara, segundo a *BP Statistical Review of World Energy June 2018*, o gás natural representa 0.23% de toda a procura de energia primária global no ano de 2017, isto deve-se talvez às suas inúmeras aplicações como, uso residencial, matéria-prima, geração de energia e combustível no sector do transporte.

Com esta versatilidade toda, o gás natural tem vindo a ser alvo de estudo e consequentemente o crescimento económico também tem vindo a ser alvo desse mesmo estudo, sendo por isso, a nossa questão de investigação: Qual a relação entre consumo de gás natural e crescimento económico, nas economias que mais consomem gás natural?

A literatura já existente nesta área não é consensual levando à existência de quatro hipóteses tradicionais que explicam esta relação causal entre consumo de energia e crescimento económico, sendo elas: hipótese de feedback, hipótese de crescimento, hipótese de conservação e hipótese de neutralidade. De igual relevância, mas não tão tradicional, é a hipótese negativa, trata-se de uma quinta hipótese que normalmente surge em economias abundantes em recursos naturais, onde ocorre uma relação negativa entre o consumo de energia e crescimento económico, é conhecida por “Maldição de recursos”.

O estudo foca dezasseis países consumidores de gás natural, considerados pelo *Index Mundi*, utilizando dados em painel com frequência anual de 1995 a 2017. Tanto o intervalo de tempo como a seleção dos países basearam-se na disponibilidade de dados, sob a condição de ser um painel balanceado. As variáveis utilizadas no estudo são Gross Domestic Product *per capita*, Natural Gas Consumption *per capita*, Gross Capital

Formation *per capita*, Employment and Carbonic Intensity of the Energy Consumed. A fim de investigar o papel do gás natural no crescimento económico foi utilizado o modelo ARDL de modo a capturar as relações dinâmicas de curto e longo prazo.

Os resultados mostram que o consumo de gás natural impulsiona positivamente o crescimento económico das economias em estudo.

Abstract

Motivated by the effects of the use of non-renewable energies such as natural gas, this dissertation aim to analyse the effect of natural gas consumption on economic growth. In this work, panel data techniques are used covering 16 cover countries, these being the largest consumers of natural gas, according to mundi index, with annual frequency and a time horizon from 1995 to 2017. The Autoregressive Distributed Lag (ARDL) model has proven to be the most suitable for capturing the dynamic relationship in short- and long-term effects. The results indicate a positive relationship between natural gas consumption and economic growth both in the short and long term application.

Keywords

Natural gas consumption; economic growth; ARDL

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Acronyms List

ARDL	Autoregressive Distributed Lag Model
CO₂	Carbon Dioxide Emissions
CIEC	Carbon Intensity of the Energy Consumed
MG	Mean Group
NGCPC	Natural Gas Consumption <i>Per Capita</i>
DFE	Dynamic Fixed Effects
D.K.	Driscoll and Kraay
EMP	Employment
ECT	Error Correction Term
FE	Fixed Effects
GCFPC	Gross Capital Formation <i>Per Capita</i>
GDPPC	Gross Domestic Product <i>Per Capita</i>
KOF	KOF Globalization Index
PMG	Pooled Mean Group
POP	Population
RE	Random Effects
VECM	Vector Error Correction Model
VIF	Variance Inflation factor

1. Introduction

Energy, a watchword in today's times, and so we must give it center value because it would be unthinkable a world without energy. Being used in our daily lives, in things as basic as in the confection of food, in heating, or simply in the charging of our mobile phone or car. Therefore, the massive use of the various energy sources of our planet has led to the need for sustainability of these and thus using new and alternative renewable energy sources, as the name says, are energy sources that do not exhaust and pollute less than conventional ones. But because these clean sources have high investment and infrastructure costs, and mainly because one can't just use clean energy to meet consumer needs, you can use conventional energy sources despite their negative impacts on the environment.

Due to the energy transition that have occurred in order to sustain people activities and their consequent impact on the environment, fits the natural gas, which is an energy source of natural origin and results from the decomposition of plant and animal organic matter, accumulated in underground natural deposits. It is therefore a fossil fuel, but despite being a non-renewable energy source it is by far the least polluting. By purifying natural gas the liquefied natural gas (LNG) is obtained, that is used in the transport sector in order to reduce greenhouse gas emissions from this sector which is one of the ones that more contributes to global warming.

As a less polluting energy source than traditional and more economical than renewables, natural gas has been the target of great impact by governments and consequently we have faced an increase in the consumption of this energy source over the last few years thus leading us to study the relationship between natural gas and economic growth in the largest consumers of this gas in the world. In addition, replacing energy sources such as coal, oil with natural gas would help lead countries to achieve the goals set by the various political agreements between countries because of climate change, such as the Kyoto Protocol and the Paris Agreement.

Energy consumption and Gross Domestic Product (GDP) tend to move together over time, thus forcing states to study the dynamic relationship that these variables have between them. This theme is a focal point on the political agenda of any state due to the growing importance that energy has in economy. According to the World Bank's World Development, the world GDP grew by an average of 2.82% from 1990 to 2017. In the same period, the total natural gas consumed, millions of tons of oil equivalent.

In 1990, according to the BP Statistical Review of World Energy June 2018, global natural gas consumption was about 1675.5 million tonnes oil equivalent (mtoe), with a significant increase compared to 2017 figures where world consumption was 3156.0 mtoe. The United States of America (USA) is the largest consumer of this fossil fuel, 635.8 mtoe. Mexico and Canada are also major consumers and so North America accounts for 25.7% of the world's total natural gas consumption in 2017. Europe is one of the continents that consumes the least of this energy source, accounting for only 14.5% of the world's share in 2017, with Germany (77.5 mtoe), United Kingdom (67.7 mtoe) and Italy (62.0 mtoe) as the most consumer countries. Iran and United Emirates Arabic are shown in the Middle East with a consumption of 184.4 and 62.1 mtoe

respectively. Russia with a consumption of 365.2 mtoe and China with 206.7 mtoe are other countries that consume a lot of this fossil fuel, thus contributing to the Asian continent being the one that holds the position of the largest consumer of natural gas, also holds the largest producer, Russia, with a production of 546.5 mtoe in 2017.

Due to the potential usage of natural gas, considering that is used worldwide as a energy transition source, backing up the higher penetration of renewables into the electricity mix, there is interest in understanding how this energy source interacts with economic growth. Given this, the main objective of this study is to examine the causal relationship between natural gas consumption and economic growth in a panel of 16 countries. In other words, the central question is: How does natural gas consumption affect the economic growth of the world's largest natural gas consumers?

Overall, this study contributes to the literature, by adding new and fresh empirical evidence of that relationship between economic growth and natural gas consumption, particularly because the focus is on a group of countries that are the largest consumers of natural gas where many are also producers of it.

Figure 1 illustrates the global evolution of the consumption of the various non-renewable energy sources. We can see that the consumption of natural gas has been growing as well as oil and coal.

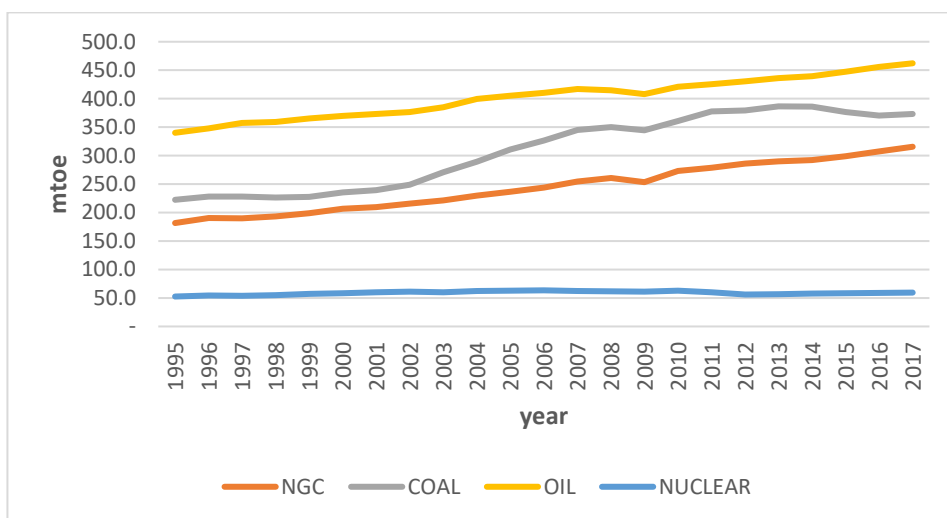


Figure 1: Evolution of World's Non-Renewable Energy Sources Consumption

SOURCE: BP Statistical Review of World Energy June 2018

The figure 1 illustrates one of the reasons that led to the realization of this dissertation, which is the increase in the consumption of natural gas.

The remainder of this dissertation is organized as follows: Section 2 involves reviewing the literature. Section 3 describes data and methodology used. The results are presented in Section 4 and discussed in Section 5. Finally, the section 6 concludes.

2. Literature Review

The large extent of the literature in this area is a mirror of the high interest and relevance of studying this relationship. Indeed, there are several authors who have been studying the relationship between energy consumption and economic growth for both developed and developing countries as well as for the short and long term. Consequently, the relationship between natural gas consumption and economic growth has also been studied, although it is not the most studied fossil energy source. Since the seminal work of Kraft and Kraft (1978) one of the first to study this relationship there has been a growing concern about energy consumption because over the years there has been an increase in the world population and greenhouse gas emissions. Consequently, the ratio of natural gas consumption and economic growth has deserved less attention in the literature.

There is no uniformity about the direction of causality between growth and economic and energy consumption because there are different studies that point to different types of relationship. Thus Apergis and Payne, (2009); Chen et al., (2007); Ozturk (2010) and more recently Brito in 2015 were example of authors who allowed to characterize the relationship between energy consumption and economic growth in 4 hypotheses: growth hypothesis, conservation hypothesis, neutrality hypothesis and feedback hypothesis. The Growth Hypothesis occurs when in an economy energy consumption leads to an increase in economic growth, that is, when there is a decrease in energy consumption this translates into a slowdown in economic growth, thus noting that energy plays a key role in economic growth and therefore conservation policies are not adequate because they can have a negative performance in a country's economy. This one-sided hypothesis of energy consumption for economic growth is advocated by Stern (1993) who studied this causal relationship for the US concluding that an increase in energy consumption leads to the country's economic development. Later, in the year 2000, Stern, extends his analysis of the previous article to the U.S. in the post-war period consolidating the results of the previous article showing that cointegration occurs between the variables. Also, this year, 2000, Yang H.Y. confirmed this hypothesis of growth for Thailand between gas consumption and GDP. Later Lee C. and Chang C. (2007) also studied Thailand, finding the same results that support this hypothesis. Bowden and Payne (2009) use Granger-causality revealing that industrial consumption of primary energy causes an increase in real GDP for the United States. Das et al., (2013) studied for a period of 30 years the causal relationship between natural gas consumption and economic growth in Bangladesh, obtaining results that support this hypothesis.

More recently, Balitskiy S. et al. in 2016 they studied the relationship between energy efficiency, natural gas consumption and economic growth for 26 Member States of the European Union where they found that an increase in economic growth leads to an increase in natural gas consumption, while the reverse is a negative relationship, i.e. natural gas consumption does not lead to an increase in GDP.

The Conservation Hypothesis is based on a one-way causality, from economic growth to energy consumption. An economy does not fully need energy consumption for economic growth, so energy conservation policies are needed. Hypothesis advocated by Kraft and Kraft (1978) found causality of GDP for energy consumption in the United States. Zhang and Cheng (2009) suggest a one-way causality of Granger ranging from GDP to energy consumption, and in the long run admit a one-way relationship between energy consumption and carbon dioxide emissions. So that long-term conservative energy policies do not impede China's economic growth. Also, in the same year, 2009, but for Pakistan, Khan A. and Ahmed U. studied the causal relationship between GDP, natural gas and adding the price of gas confirmed the existence of the conservation hypothesis, where they used Johansen's method. Payne (2011) also revealed that there is a one-way relationship between economic growth and natural gas consumption in the US.

The Feedback hypothesis occurs when there is a relationship between energy consumption and economic growth, as well as between economic growth to energy consumption. That is, when economic growth varies, the same variations occur in energy consumption and vice versa. Zamani M. (2007) studied this theme in Iran, concluding that there is bidirectional causality between natural gas consumption and economic growth. Lee et al. (2008) using a panel cointegration analysis and the VECM, for a panel of 22 OECD countries, observe the existence of two-way causal relationships between variables, energy consumption and economic growth. Also, Hu J. and Lin C. in the same year, 2008, confirmed this feedback hypothesis between the variables, consumption of natural gas and real GDP. Belloumi M. (2009) found that for Tunisia there is a two-way causal relationship between GDP per capita and per capita energy consumption by a long-term cointegration vector. Belke et al. (2011) found that there is a two-way causal relationship between energy consumption and economic growth through the long-term study of variables, energy consumption, real GDP, and energy prices for 25 OECD countries. Fuinhas J. and Marques A. in 2012 studied the economies of southern Europe, for which they found bidirectional causality between energy and growth both in the long and short term using an ARDL approach. Also, in the same year, Kum et al. (2012) studied the relationship between natural gas consumption and economic growth for the G-7 countries, concluding that only in France, Germany, and the United States there is a hypothesis of feedback.

The Neutrality hypothesis indicates that energy conservation policies have no effect on growth, as there is no causal relationship between energy consumption and growth. Simply put, the two variables have a neutral relationship. This hypothesis is defended for Yu and Choi in 1985, using the Sims causality test was founded the hypothesis of neutrality between the consumption of natural gas and economic growth for Poland and the USA. Lee C. (2006) analysed a panel of countries, finding only for the United Kingdom, Germany, and Sweden the neutral relationship between energy consumption and income, thus supporting this hypothesis of neutrality. Akinlo, A. (2008) using an ARDL approach studies this causal relationship for 11 African countries, noting that only for Cameroon, Cote D'Ivoire, Nigeria, Kenya and Togo show a zero causality between energy consumption and economic growth.

Alam J. M. et al. (2011) studies the relationship between energy consumption, carbon dioxide emissions and income and concludes that in the long term there is no causal relationship between energy consumption and income in India.

Finally, Negative hypothesis that translates when in an economy energy consumption has a negative impact on economic growth in rich countries, that is, the excessive increase in energy consumption has a negative impact on economic growth, and also as the economy grows there is a decrease in energy consumption. This is not a traditional hypothesis, but it has been evident and is related to the concept of "resource curse".

The negative hypothesis is advocated by Squalli (2007) who found that if the government devises policies to promote access to energy and higher consumption, economic growth will not be affected, this for Russia. Apergis & Payne (2010b) studied several countries from 1980 to 2006 and found that long-term coal consumption has a significant negative impact on real GDP. Fuinhas & Marques (2013) found for Algeria, which is an economy with a high rentierism, the negative hypothesis. More recently, Alam, Paramati, Shahbaz, & Bhattacharya in 2017 also support this negative hypothesis.

This study is an addition to the existing literature because it has a more recent time horizon, presenting more knowledge in relation to the development of the development that occurred and the current energy transition. As well, the study of natural gas consumption and carbon intensity of energy consumption in countries considers the largest consumers of natural gas is an existing flaw in the literature.

3. Data and Methodology

3.1 Data

This study focuses on the relationship between natural gas consumption and economic growth. Considers all available data for both time and countries to be able to have a balanced panel. We thus have a panel of 16 countries, within which we have the largest consumers of natural gas in the world according to Index Mundi: Argentina, Canada, China, Egypt, Germany, India, Iran, Italy, Japan, Korea Republic, Mexico, the Russian Federation, the United Kingdom, the United States, Thailand and Turkey and a time horizon from 1995 to 2017 with annual data.

The Gross Domestic Product (constant LCU) and Gross Capital Formation (constant LCU) were sourced from World Development Indicators. Data on natural gas consumption were taken from BP Statistical Review of World Energy June 2018, with Million tons oil equivalent (Mtoe). The employment variable was calculated by multiplying unemployment by the Labour Force, then divided by 100, and finally this value was withdrawn from the labour force and thus we obtained the employment value. Also, the variable Carbon Intensity of the Energy Consumed was calculated by dividing CO₂ emissions and Natural Gas Consumption. The econometric analysis was performed using Stata software. In short, the variables used are: (i) GDPPC (Gross Domestic Product *per capita*); (ii) NGCPC (Natural Gas Consumption *per capita*); (iii) GCFPC (Gross Capital Formation *per capita*); (iv) CIEC (Carbon Intensity of the Energy Consumed); (v) EMP (Employment).

All variables were transformed into per capita by their ratio and population except for EMP and CIEC. Also, all variables were converted into logarithmic form.

The dependent variable, GDPPC is used as a proxy for economic growth, as is often used in the literature. The NGCPC variable was chosen to test the relationship between natural gas consumption and economic growth. The variables GCFPC, CIEC and EMP were added as control variables. The GCFPC was introduced as an investment measure, the EMP is inserted as a work measure and the CIEC was introduced as an energy measure because it analyses greenhouse gas emissions in relation to natural gas consumption.

Next, we have Figure 2 that illustrates the CIEC variable, which relates CO₂ emissions with the consumption of natural gas in each country.

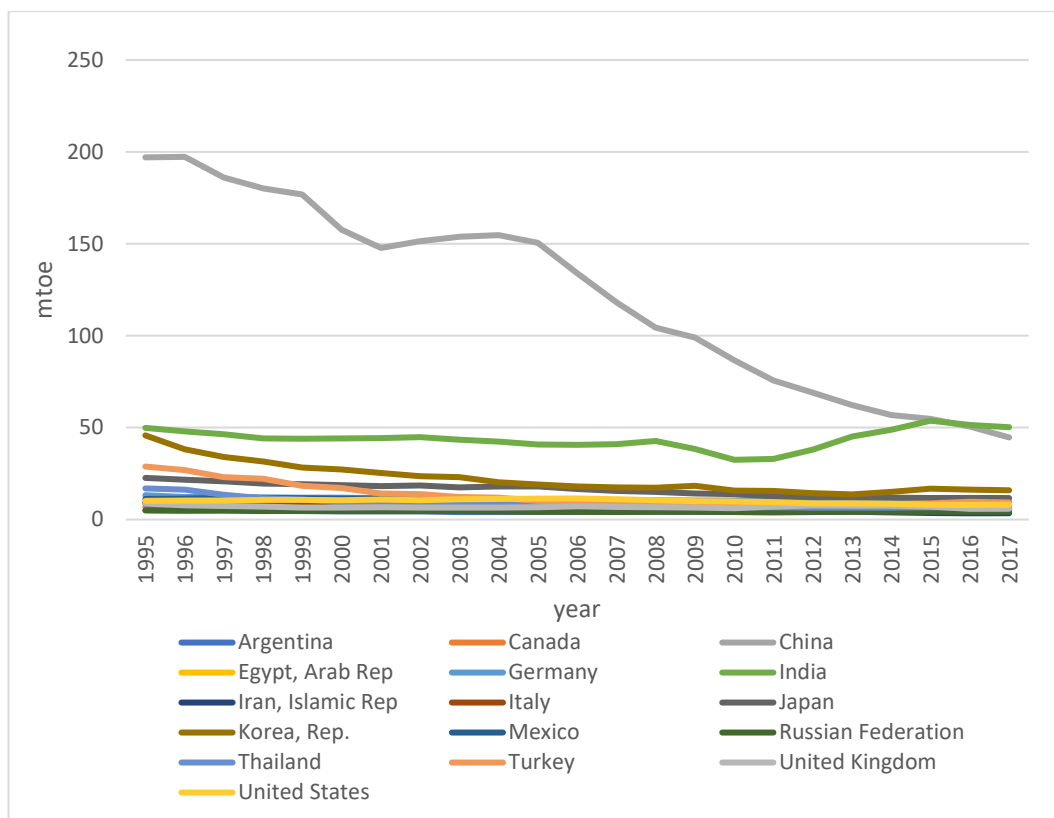


Figure 2: Evolution of Carbon Intensity of the Energy Consumed

SOURCE: BP Statistical Review of World Energy June 2018

Figure 2 illustrates the development of the CIEC variable compared to the 16 countries under study. This variable, CIEC, is important because we illustrate the amount of cO₂ that is released into the atmosphere in relation to the natural gas consumed. China and India stand out for the high carbon dioxide emissions, especially China. Evidence of severe reduction over the years, we can see that in 1995 it issued about 197 mtoe of Co₂ emissions per natural gas consumed while in 2017 it issued only 44 mtoe, an abrupt reduction. In relation to the other countries, we can observe that over these 22 years the Carbon Intensity of the Energy Consumed was always below 50 mtoe and there was also a slight decrease in these emissions.

3.2 Method and preliminary tests

To verify that there is a relationship between the consumption of natural gas and the economic growth of these 16 countries under study, the autoregressive distributed lag (ARDL) cointegration technique model was used. This model is useful when analysing the effects both in the short and long term, and has an advantage of being able to deal with variables such as I(0) and I(1). As variables are in natural logarithms, to make as nonlinear relationships as linear as possible. Hereafter, the prefix “L” denote natural logarithm and “D” denote first difference of the variable. The variables in natural logarithms and in first differences represents the long and short term, respectively. The ARDL model, Eq, the following:

$$\begin{aligned}
 LGDP_{it} = & \alpha_{1i} + \beta_{i1}LGDP_{it-1} + \beta_{i2}LNGCPC_{it} + \beta_{i3}LNGCPC_{it-1} + \beta_{i4}LGCFPC_{it} \\
 & + \beta_{i5}LGCFPC_{it-1} + \beta_{i6}LCIEC_{it} + \beta_{i7}LCIEC_{it-1} + \beta_{i8}LEMP_{it} \\
 & + \beta_{i9}LEMP_{it-1} + \varepsilon_{it}
 \end{aligned} \quad (1)$$

Eq. (1) can be re-parameterized into the general UECM form, Eq. (2), in order to capture the dynamic relationship among variables, as follows:

$$\begin{aligned}
 DLGDP_{it} = & \alpha_{1i} + \beta_{i1}DLNGCPC_{it} + \beta_{i2}DLGCFPC_{it} + \beta_{i3}DLCIEC_{it} + \beta_{i4}DLEMP_{it} \\
 & + \lambda_{i1}LGDP_{it-1} + \lambda_{i2}LNGCPC_{it-1} + \lambda_{i3}LGCFPC_{it-1} + \lambda_{i4}LCIEC_{it-1} \\
 & + \lambda_{i5}LEMP_{it-1} + \varepsilon_{it}
 \end{aligned} \quad (2)$$

where α_i denotes the intercept, β_i he estimated parameters, and ε_{it} the error term. Descriptive statistics for all variables can be seen in Table1.

Table 1. Descriptive statistics

Variables	Descriptive statistics				
	Obs	Mean	S. D.	Min.	Max.
<i>LGDPCC</i>	368	11.83652	2.555012	9.153749	18.30356
<i>LNGCPC</i>	368	-14.41963	1.297836	-18.17697	-12.81362
<i>LGCFPC</i>	368	10.386	2.706311	7.125697	17.3249
<i>LCIEC</i>	368	2.370528	.8708436	1.234486	5.28473
<i>LEMP</i>	368	14.88349	1.108243	12.16447	17.41493
<i>DLGDPPC</i>	352	.0248609	.0355185	-.1261845	.1278324
<i>DLNGCPC</i>	352	.036999	.0681328	-.1920738	.2689953
<i>DLGCFPC</i>	352	.0273838	.1188299	-.6702194	.56497
<i>DCIEC</i>	352	-.026666	.0536395	-.1955919	.1713362
<i>DLEMP</i>	352	.0026821	.1447233	-.4150486	1.368484

The presence of cross-sectional dependence is expected, because the economies in studies are producers of natural gas too, so we proceed to the realization of 2nd Generation panel unit root test CIPS (Pesaran, 2007).

The results of the CD test proved that cross-sectional dependence was detected for all variables. The CIPS test reveals that the variables are I(0) and I(1) which leads us to the use of the ARDL approach.

Table 2. Cross-sectional dependence (CD-test) and 2nd Generation panel unit root test (CIPS)

Variables	Cross-section dependence			2nd Generation panel unit root test CIPS	
	CD-test	corr	abs(corr)	No trend	Trend
<i>LGDPCC</i>	42.76***	0.814	0.819	-3.284***	-2.051**
<i>LNGCPC</i>	23.55***	0.448	0.611	-1.154	1.791
<i>LGCFPC</i>	21.15***	0.403	0.560	-3.996***	-2.265**
<i>LCIEC</i>	31.96***	0.608	0.631	1.204	1.111
<i>LEMP</i>	1.49	0.028	0.442	-0.865	0.316
<i>DLGDPPC</i>	15.61***	0.304	0.324	-1.687**	0.044
<i>DLNGCPC</i>	6.76***	0.131	0.217	-4.903***	-3.083***
<i>DLGCFPC</i>	12.65***	0.246	0.308	-2.863***	-0.724
<i>DLIEC</i>	1.32	0.026	0.232	-4.497***	-2.821***
<i>DLEMP</i>	9.92***	0.193	0.266	-2.228***	-0.111

Notes: CD-test has N(0,1) distribution, under the Ho: cross-section independence; Pesaran (2007) Panel Unit Root test (CIPS): series are I(1); the presented results include 1 lag; ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

The presence of cross-sectional dependence was proven for all variables. We verified the presence of collinearity, as it is advisable when working for long periods. Correlation coefficients between variables that allow us to observe as correlations between the dependent variable and as

independent variables in table 3. The VIF test was performed to verify the multicollinearity between the variables.

Table 3. – Matrices of correlation and VIF statistics.

	<i>LGDP</i>	<i>LNGCPC</i>	<i>LGCFPC</i>	<i>LCIEC</i>	<i>LEMP</i>
<i>LGDP</i>	1.0000				
<i>LNGCPC</i>	0.2069	1.0000			
<i>LGCFPC</i>	0.9953	0.1650	1.0000		
<i>LCIEC</i>	-0.0734	-0.8276	-0.0158	1.0000	
<i>LEMP</i>	-0.2089	-0.4740	-0.1748	0.5516	1.0000
VIF		3.43	1.12	3.82	1.50
Mean VIF			2.47		

	<i>DLGDP</i>	<i>DLNGCPC</i>	<i>DLGCFPC</i>	<i>DLIEC</i>	<i>DLT</i>
<i>DLGDP</i>	1.0000				
<i>DLNGCPC</i>	0.3919	1.0000			
<i>DLGCFPC</i>	0.7930	0.2845	1.0000		
<i>DLIEC</i>	-0.0337	-0.7966	0.0376	1.0000	
<i>DLT</i>	-0.4302	-0.0966	-0.5296	-0.1270	1.0000
VIF		3.78	1.71	3.52	1.42
Mean VIF			2.61		

The variable LCIEC and LEMP are negatively correlated with the dependent variable. The average VIF that collinearity is not a problem because the value of the VIF mean is still far from the value 10.

4. Results

We performed the Hausman test that compared fixed effects (EF) with random effects (RE) estimators. Hausman's statistically significant p-value value led to the rejection of the null hypothesis, ($\chi^2=21.44^{***}$). We reject the null hypothesis which considers that the model of random effects, so the fixed effects model was used.

After this, the Pooled Mean Group (PMG) and the estimators of Mean Group (MG) were applied to answer any doubts regarding the existence of heterogeneity, because the countries targeted studies have economies disparities. And to verify which test was appropriate to use, the Hausman test was performed once again. The results of the MG and PMG estimator will be tested against the dynamic EF estimator. Table 5 summarizes the results of the three estimators (Pooled Mean Group - PMG, Mean Group -MG and Dynamic Fixed Effects -DFE estimators), as well as the Hausman test.

Table 4. Heterogeneous estimators and Hausman test

Models	PMG	MG	FE
Constant	.45361064***	3.8407868***	.78511664***
<i>DLNGCPC</i>	.09477137***	.08933328***	.12304747***
<i>DLGCFPC</i>	.19919327***	.18348635***	.19355198***
<i>DLCIEC</i>	.11285542***	.0565626	.12228923***
<i>DLEMP</i>	-.04261664***	-.03137209***	-.02029998***
<i>ECT</i>	-.07671572***	-.27679971***	-.06183021***
<i>LNGCPC(-1)</i>	-.0537192	2.1614148	.42352826**
<i>LGCFPC(-1)</i>	.59173802***	.80263943	.43162792***
<i>LCIEC(-1)</i>	-.09068936*	1.1936735	.33901463
<i>LEMP(-1)</i>	-.0396409*	.23337294	.01691857
<i>Hausman Tests</i>	MG vs PMG	PMG vs FE	MG vs FE
<i>Chi2(4)</i>	3.57	0.00	0.00

Notes: ***, ** and * denote statistical significance at 1%, 5% and 10% level, respectively.

According to Table 4, the fixed effects estimator demonstrated that it is the most appropriate to use. The Westerlund test (2007) was performed using the bootstrapping option, to verify the presence of co-integration between the variables in order to test the cointegration, as shown in Table 5.

Table 5. Westerlund (2007) co-integration test

Statistics	Value	Z-value	P-value	Robust P-value
Gt	-1.508	2.289	0.989	0.789
Ga	-4.889	2.701	0.997	0.763
Pt	-4.099	2.666	0.996	0.793
Pa	-2.3000	2.550	0.995	0.773

Notes: The null hypothesis of the Westerlund co-integration test is no co-integration; bootstrapping regression with 800 reps; Gt and Ga test the cointegration for each country individually, and Pt and Pa test the cointegration of the panel as whole; the Stata routine *xtwest* (with constant option) was used.

The outcomes from the Westerlund co-integration test (Table 5) proves that the presence of co-integration is rejected.

To verify the presence of heteroskedasticity, the Modified Wald test was performed. Then, the contemporary correlation between the cross-section was tested by the Pesaran test option. Finally, to verify the presence of serial correlation, the Wooldridge test for autocorrelation was also computed. The results of the specification tests can be seen in Table 6.

Table 6. Specification tests

	Statistics
Modified Wald test	1061.33***
Wooldridge test	7.816**
Pesaran's test	1.992**

Notes: ***, denote significance at 1%; The Modified Wald test tests the null hypothesis of homoscedasticity; The Wooldridge test tests the null hypothesis of no first-order autocorrelation; The Pesaran's tests the null hypothesis of cross-sectional independence.

The results of table 6, demonstrate, through the Modified Wald Test concludes that heteroscedasticity exists, through the Pesarn Test we verified that there is a contemporary correlation and, finally, the result of the Wooldridge test confirms the existence of autocorrelation.

The estimator Driscoll and Kraay (Driscoll & Kraay, 1998) was used after the presence of heteroskedasticity, contemporary correlation and first-order autocorrelation were verified. This estimator is a matrix estimator that produces robust standard errors to various phenomena, namely those found in sample errors. The results of the FE model, FE model with robust standard errors (robust), and Driscoll and Kraay estimator (D.K.), are presented in table 7.

Table 7. Estimations results

Models	Coefficients	FE	FE Robust	D.K. FE
Constant	.78511664	***	***	***
<i>DLNGCPC</i>	.12304747	***	***	***
<i>DLGCFPC</i>	.19355198	***	***	***
<i>DCIEC</i>	.12228923	***	***	***
<i>DLEMP</i>	-.02029998	***		*
<i>LGDPPC (-1)</i>	-.06183021	***	***	***
<i>LNGCPC (-1)</i>	.02618684	***	**	***
<i>LGCFPC (-1)</i>	.02668764	***	*	**
<i>LCIEC (-1)</i>	.02096134	*		***
<i>LEMP (-1)</i>	.00104608			
<i>Diagnostic statistics</i>				
<i>N</i>		352	352	352
<i>R²</i>		.73693421	.73693421	
<i>R² adjusted</i>		.71762662	.73001142	
<i>F</i>		F(9,327)= 101.78*** F(9,15) = 79.95*** F(9, 15) = 25.44***		

Notes: ***, ** and * denote statistically significance at 1%, 5% and 10% level, respectively.

Table 8 refers to semi-elastic and elastic, where the short- and long-term impacts/elasticities. Note that the long-term elasticities are not directly provided by estimates, contrary to short-term semi-elastic. The elasticities were obtained by dividing the coefficient of the variables by the coefficient of LGDPPC, both lagged once and multiplied the ratio by -1.

Table 8. Elasticities, semi-elasticities, impacts, and adjustment speed.

Models	Coefficients	FE	FE Robust	FE D.K.
<i>Short-run elasticities</i>				
Constant	.78511664	***	***	***
<i>DLNGCPC</i>	.12304747	***	***	***
<i>DLGCFPC</i>	.19355198	***	***	***
<i>DLCIEC</i>	.12228923	***	***	***
<i>DLEMP</i>	-.02029998	***		*
<i>Long-run elasticities</i>				
<i>LNGCPC (-1)</i>	.4235283	**		***
<i>LGCFPC (-1)</i>	.4316279	***	***	***
<i>LCIEC (-1)</i>	.3390146			**
<i>LEMP (-1)</i>	.0169186			
<i>Speed of adjustment</i>				
ECT	-.06183021	***	***	***

Notes: ***, ** and * denote statistically significance at 1%, 5% and 10% level, respectively; ECT means Error Correction Term.

Table 7 demonstrate the estimates of the FE, FE Robust and Driscoll-Kraay models in the long term while table 8 presents the same estimates, but in the short term.

As we can observe, in the short term, all variables are positive and highly significant at 1% except for the variable Employment which is significant only at 10%, in the Discoll-Kraay model. These results reveal that there is a statistical relationship between Gross Domestic Product and Natural Gas Consumption, Gross Capital Formation and Carbon Intensity of the Energy Consumed, all of which positively influence economic growth. The DLNGCPC according to the Discoll-Kraay model indicates that the 1 p.p. growth in natural gas consumption causes economic growth to grow by .123%. Gross capital formation by 1 p.p. means an increase in the LGCDPC of .194%, it is also the variable studied in this model that has a greater impact on economic growth. CIEC's 1 p.p. growth means a .122% increase in economic growth in the countries under study. Finally, finally we have the variable Employment, but it is not highly statistically significant for the model.

In the long run, too, all variables are positive and highly significant at 1% except for CIEC variables which is significant only at 10% and the EMP variable is not significant. Again, the results mean that there is a positive statistical relationship between economic growth and the other variables, except for the EMP variable. The LNGCPC according to the Discoll-Kraay model indicates that its growth of 1% causes .423%. the growth of the LGDPPC. The LGCFPC at 1% means an increase in the LGDPPC of .432%. The 1% growth of Carbonic Intensity of the Energy Consumed means a .339% increase in economic growth in the countries under study. Lastly, we have the employment variable, contrary to the short term, presents a positive value, but is not statistically significant for the model.

ECT value is -0.062, low value for there is a real adjustment mechanism, that is, the correction is slow and the shocks that exist take time to be absorbed, however the value is negative.

5. Discussion

The focus that natural gas has been having is due to the fact that it has already mentioned its numerous advantages over other conventional sources, highlighting two in particular. It allows consistent support to renewable energy sources and is also a less polluting fuel within the fossil fuels alternatives. Given all these benefits of natural gas, the scale of use of natural gas has been increasing and we have studied how it affects the economies of the countries that consume it the most. They are countries that, in addition to consuming a lot of natural gas, also produce it, making them self-sufficient in the consumption of natural gas. Russia and the United States of America are a great example, which are the largest consumers and producers of natural gas, where Russia exports mostly in turn to Europe, while the U.S. cares more about meeting its high demand. We know that they have a high level of natural gas consumption, but does this affect the economic growth of the range of countries under study?

We have seen a positive effect from natural gas consumption on economic growth in. It should be noted that it meets the existing literature, where several studies such as Gideon Fadiran et al., (2018) indicate the same effect. Natural gas has a strong implication in the development of economies both in the short and long term.

Some economic growth factors have also been detected, such as capital fixed formation, employment and carbonic intensity of the energy consumed. We found that gross capital formation has a positive relationship both in the short and long term, especially in the short term. The same effect is reported by Mehmet Akif Destek (2015). Regarding Employment, the results demonstrated that there is a negative relationship in the short term, little expressed, but still negative but in the long run we have not any statistically significant. This result of a negative relationship is unexpected but may be related to the fact that the countries under study are also mostly producers of natural gas and thus there are cases in the literature but Al Mamun et al., (2017) have the same results about employment. This may occur because natural resources such as Natural Gas are not produced, but rather extracted and extraction is capital intensive. In short, if the manpower for the extraction of these resources is not qualified for this particular industry it could lead to a negative impact on the economy of the producing country. The results for Carbonic Intensity of the Energy Consumed present a positive relationship, i.e. the proportion of carbon dioxide emissions emitted by natural gas consumption has a positive impact on the economic development of the countries under study.

The results presented in this study lead the governments of the countries under study to reflect and harness the power of natural gas, as the results show that the consumption of natural gas contributes to the development of countries, and thus should analyse and idealize economic measures to replace the so-called conventional energy sources. Natural gas consumption demonstrated a strong short- and long-term relationship in these economies and therefore the implications of consumption of this non-renewable source should be considered, therefore, 1 p.p. of NGCPC leads to .123% and .423% of GDP growth, respectively.

Given the way energy changes have occurred in recent years, largely due to known climate change that is largely a consequence of pollution related to conventional sources, this leads to a constant demand for alternatives in which natural gas has played a key role. We can say that this study indicates that natural gas is a viable source, although as non-renewable energies can resist as clean energies in this energy transition. In this way, we can see that the consumption of this source, together with renewable energies, is beneficial for reducing carbon dioxide emissions and promoting wealth in each country.

We can see that everything leads us to want natural gas to be one of the "sources of the future", which will replace backup energy sources as well as may replace conventional energy sources in the transport sector, as has already been seen. However, this range of countries should be concerned with having alternative sources to them to promote the energy sustainability of their economies.

6. Conclusion

This study essentially explored the relationship between natural gas consumption (NGCPC) and economic growth (GDPPC) in 16 countries, among them the largest consumers of natural gas in a time horizon that encompasses the energy transition that has been occurring, 1994-2017. After all the proper specification tests, we found that the ARDL approach was the most appropriate for model estimation, thus allowing short- and long-term study to verify the behaviour of natural gas consumption in the economic growth of this range of countries covered.

The results show that natural consumption, gross capital formation and carbon intensity of the energy consumed have a very significant positive relationship with short- and long-term economic growth. Employment has a negative relationship that is not significant in the short term, a relationship that is not expected since it is negative for economic growth, and in the long term there is no relationship.

According to the results obtained, we can conclude that natural gas must become the conventional energy source with the most consumption, because its advantages outweigh the disadvantages and thus is the most appropriate for the intermittent sources to carry out the energy transition that is already taking place. Given this, the consumption of natural gas is an asset for the economic development of a country.

In the future, and looking for assure additional robustness of the results obtained, more consumer countries and natural gas producers could be covered, as well as the introduction of a variable that it considers as issues of globalisation.

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