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Is there a resource curse phenomenon for natural gas? Evidence from abundant countries

Patrícia Silva Pires

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Orientador: Prof. Doutor António Manuel Cardoso Marques

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Resumo

Este estudo centra-se no nexo crescimento económico-gás natural e pretende testar a hipótese de “maldição dos recursos”. Técnicas de dados em painel foram aplicadas para investigar o papel do gás natural no crescimento econômico, para 25 produtores de gás natural, de 1993 a 2015. Consequentemente, três diferentes abordagens foram usadas e comparadas, para testar a hipótese de “maldição dos recursos": produção, reservas e rendas. 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. Foi utilizado o estimador Driscoll-Kray com efeitos fixos, dada a presença dos fenômenos de heterocedasticidade, autocorrelação de primeira ordem, correlação contemporânea e dependência transversal. Os resultados sugerem que o consumo de gás natural impulsiona o crescimento económico tanto a curto como a longo prazo. A presença do fenómeno da maldição dos recursos não foi validada para nenhuma das três abordagens. Os formuladores de políticas devem perceber as características do gás natural como fonte de transição. De facto, o gás natural não se enquadra no padrão de dependência, como é historicamente observado nos países produtores de outros recursos, como o petróleo.

Palavras-chave

Crescimento Económico, Gás Natural, Maldição dos Recursos, ARDL

Resumo Alargado

Para atender ao crescente aumento das necessidades energéticas mundiais e às preocupações ambientais, as economias mundiais estão a alterar a sua matriz energética para produção de energia de baixo carbono. O gás natural é uma fonte de energia não renovável que desempenha um papel cada vez mais importante na economia global, em grande parte pelas suas vantagens ambientais. In 2017, natural gas represented 23.4% of global primary energy demand. Esta fonte de energia tem uma variedade de aplicações, incluindo: uso residencial, matéria-prima para a indústria, geração de energia e transporte. Com o aumento do uso desta versátil fonte de energia, existe um interesse em compreender se o gás natural poderá estar associado ao fenómeno conhecido na literatura como a "maldição dos recursos". Tendo isto em consideração, a questão central é: os países aprenderam com os outros hidrocarbonetos, a saber, o petróleo, a maldição dos recursos?

A literatura é escassa nestes estudos sobre o fenómeno da maldição dos recursos e o gás natural, já quanto à relação com outros hidrocarbonetos ou minerais a literatura é extensa. Contudo, os resultados estão longe de ser consensuais. Alguns estudos empíricos validam a hipótese da maldição dos recursos, outros encontram um efeito positivo dos recursos naturais sobre o crescimento e, assim, fornecem evidências contra a hipótese de maldição dos recursos, e outros não encontram nenhum efeito. Além da relação entre o fenómeno da maldição dos recursos e o gás natural, também a relação entre o consumo de energia primária e o crescimento económico é testada, destacando-se quatro hipóteses tradicionais: hipótese de *feedback*, hipótese de crescimento, hipótese de conservação e hipótese de neutralidade. Contudo, e apesar de menos comum, existe outro tipo de relação causal do nexo crescimento-energia. A relação negativa entre o consumo de energia e o crescimento económico tem sido encontrada na literatura empírica geralmente em economias abundantes em recursos naturais.

O estudo foca vinte e cinco países produtores de gás natural, utilizando dados em painel com frequência anual de 1993 a 2015. 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 o produto interno bruto (PIB), a produção de gás natural, as reservas de gás natural, as rendas do gás natural, o consumo de energia primária, a formação de capital fixo, o *KOF Globalization index* e o emprego. A fim de investigar o papel do gás natural no crescimento económico, três abordagens foram desenvolvidas e confrontadas, sendo elas: a abordagem da produção, a abordagem das reservas e a abordagem das rendas. A necessidade de serem desenvolvidas três abordagens diferentes prende-se pelo facto de as duas primeiras abordagens (produção e reservas) serem abordadas para analisar o papel da abundância do gás natural no crescimento económico. A última, (rendas), para analisar o papel da dependência (económica) das receitas do gás natural no crescimento económico. Estas abordagens procuram assim avaliar a relação com o PIB, ou seja, com o crescimento econômico. Para tal, recorreu-se/utilizou-se o modelo ARDL para capturar as relações dinâmicas tanto de curto como de longo prazo, separadamente.

Os resultados mostram que hipótese da "maldição do gás" não foi validada. Existem diferenças significativas entre o uso da abordagem da abundância e da abordagem da dependência. Por um lado, a abundância do gás natural parece promover o crescimento económico. Por outro lado, a dependência de gás natural não tem impacto no crescimento económico, nem a curto nem a longo prazo. Em suma, estas descobertas sustentam que o gás natural, além das suas vantagens ambientais, pode ser um apoio à diversificação do *mix* energético destes países, reduzindo a dependência dos recursos tradicionais de combustíveis fósseis, como o petróleo.

Abstract

This study focuses on the natural gas-economic growth nexus and intends to test the hypothesis of “resource course”. Panel data techniques were applied to investigate the role of natural gas in economic growth, for 25 producers of natural gas, from 1993 to 2015. Consequently, three different approaches were used and compared, in order to test the “resource curse” hypothesis, namely: production, reserves, and the rents approach. Due to the data characteristics, the Autoregressive Distributed Lag model (ARDL) proved to be the most suitable for capturing the dynamic relationship in short- and long-run effects. The Driscoll-Kray estimator with fixed effects was used, given the presence of the phenomena of heteroscedasticity, first order autocorrelation, contemporaneous correlation and cross-sectional dependence. Results suggest that natural gas consumption drives economic growth in both the short- and long- run. The presence of the resource curse phenomenon was not validated for any of the three approaches. Policymakers should realize the characteristics of natural gas as a transition source. Indeed, natural gas does not fit the pattern of dependency as is historically observed in producers’ countries for other resources, such as oil.

Keywords

Economic growth, Natural gas, Resource curse, ARDL

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Tables list

Acronyms List

ARDL	Autoregressive Distributed Lag Model
CO_2	Carbon Dioxide Emissions
COM	Primary Energy Consumption
CPI	Consumer Price Index
D.K.	Driscoll and Kraay
ECT	Error Correction Term
EMP	Employment
FE	Fixed Effects
GASP	Natural gas price
GCF	Gross Capital Formation
GDP	Gross Domestic Product
KOF	KOF Globalization Index
MG	Mean Group
PAP	Production Approach
PMG	Aggregate Mean Group
POP	Population
PROD	Natural Gas Production
RAP	Reserves Approach
RE	Random Effects
RES	Natural Gas Reserves
RGAS	Natural Gas Rents
RTAP	Rents Approach
VIF	Variance Inflation factor
UECM	Unrestricted Error Correction Model

1. Introduction

Natural gas is widely used around the world for a variety of applications, namely power generation, residential use, transportation and industry. It is a non-renewable energy source which plays an important role in the global energy mix. In 2017, natural gas represented 23.4% of global primary energy demand. Furthermore, it has been the source with highest growth (BP Statistical Review of World Energy, June 2018) worldwide. The natural gas supply chain is composed of: production, transmission, trading and the market. This source is promising to substitute oil, coal and other fossil fuels sources, due to its environmental comparative advantages. Indeed, natural gas emits fewer pollutants than other non-renewable sources and it is the cleanest burning conventional fossil fuel (Cohen, 2018). In such a way, some governments have been exploring policy options to increase the usage of natural gas. China, for example, increased natural gas consumption by more than 15% in 2017, through the "coal-to-gas switching" scenario (BP Statistical Review of World Energy, June 2018). The participation of natural gas, in the current energy structure can be fundamental as a complementary support for renewable energy sources, acting as back up energy in the diversification mix, promoting higher penetration of intermittent renewables and reducing air pollution, thus contributing to welfare and economic development.

Owing to the potential of natural gas, there is an interest in understanding if this energy source could be associated with the phenomenon called "resource curse". According to this phenomenon, resources rich countries, those with oil, natural gas, coal and other non-renewable resources, tend to grow slower than countries with fewer natural resources. In fact, some of these countries experience developmental failures and low levels of income. Given the above background, the main aim of this study focuses on exhaustively testing the hypothesis of the "resource course" with regard to countries with abundant natural gas sources. In other words, the central question is: have countries learned from the hydrocarbons, namely oil, resource curse? To the best of our knowledge, studies that test the resource curse hypothesis in the natural gas scenario, remain very scarce in the literature.

This study contributes to the literature mainly in the following aspects. First, the focus is on a group of countries that are natural gas producers, many also being natural gas net exporters. By taking these countries as a panel, the study controls the specificities of natural gas economies. Second, three approaches were used to test the hypothesis of "resource course", namely: production, reserves and the rents approach. In this way, the production and the reserves approach were chosen to assess the abundance of natural gas, and the rents approach to assess the (economic) dependence from natural gas in the 24 selected countries. Third, the causal relationship between primary energy consumption and economic growth is also examined. Note that, dependence on, or the abundance of a natural resources could lead to an unusual relationship between energy consumption and economic growth (Fuinhas & Marques, 2013).

The results show that the “resource curse” hypothesis has not been validated for any of the three approaches. Also, the usage of the abundance approach and the dependence approach show different outcomes. Natural gas abundance has a positive impact on economic activity, while natural gas dependence has no impact. This study could be insightful for natural gas abundant countries to prevent them falling into the trap of the “resource curse”, given the growing usage and potential of the natural gas source.

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

2. Literature Review

The present subsection starts with a brief discussion of the energy-growth nexus literature and the analysis of the resource curse phenomenon. The next subsection pointed out the literature on the resource curse phenomenon and the main channels that could cause the resource curse. Finally, the last subsection presents the debate about the role of natural gas in the resources curse.

2.1 Framework of energy-growth nexus

The causal relationship between energy consumption and economic growth has been intensively studied. Understanding of the complexity of this relationship is very important when designing energy efficiency policies that can contribute to the promotion of sustainable development. In 2017, global energy consumption increased by 2.2%, led by natural gas and renewable energy (BP Statistical Review of World Energy, June 2018). Indeed, renewable energy sources and natural gas have been the critical sources in the diversification mix goal worldwide.

The energy-growth nexus studies are based on the positive causality between energy consumption and growth, distinguished four main hypotheses: the *"growth hypothesis"*, the *"feedback hypothesis"*, the *"neutrality hypothesis"*, and the *"conservation hypothesis"* (Ozturk, 2010; Hajko, 2017; Tiba & Omri, 2017). Although the negative impact of energy consumption on economic growth is not so common, was found in some resource-rich countries by Squalli (2007) and Apergis & Payne (2010b) and Alam, Paramati, Shahbaz, & Bhattacharya, (2017). On the one hand, excessive energy consumption in unproductive sectors and an inefficient energy supply, can explain this negative effect on growth. On the other hand, as the economy grows, a decrease in energy consumption may be necessary to shift production to sectors with less energy consumption, such as services. In fact, natural resources abundance may influence the causality between energy consumption and economic growth (Fuinhas & Marques, 2013). In some resource-rich countries, natural resources do not promote economic and social development (Bulte, Damania, & Deacon, 2005).

2.2 Resource Curse

The relationship between the natural resources and economic growth led to an extensive literature, but the difficult question remains: natural resource abundance impedes or facilitates economic growth? There is a strong evidence that, in some cases, the natural resources do not translate into a blessing for the economy but are associated to the so-called "resource curse". The "resource curse", coined by Auty (1993), refers to the paradox that resource-rich countries - thus that are endowed with oil, natural gas, minerals and other non-renewable resources - tend to have weak economic and social performance when compared to countries which are not endowed with natural resources.

The resource curse phenomenon can be measured either by two approaches: the natural resource dependence (the degree to which countries have access to sources of income from the exploitation of natural resources) and the natural resource abundance (country´s estimated subsoil wealth, such deposits of oil, gas and minerals). The individual analysis of this two approaches can led to different results, such as found by Brunnschweiler & Bulte (2008) and Shahbaz, Akif, Okumus, & Sinha (2019). For instance, Brunnschweiler & Bulte (2008) argued that the resources rents inflows can represent a bigger problem to the economic activity and to the quality of institutions than the subsoil wealth. Resource dependence generally occurs when there are no diversification of production structure and exports, making countries heavily reliant on the natural resources' revenues (Badeeb, Lean, & Clark, 2017).

To explain the negative relationship between natural resources and economic growth, some causal channels are pointed out in the literature. The Dutch Disease phenomenon is one of the most frequently mentioned explanations (W. Max Corden & Neary, 1982; Corden, 1984; Krugman, 1987). The concept was coined by "The Economist" in 1977, when the Dutch manufacturing sector experienced a decline after the discovery of large natural gas sources in Groningen, Netherland, during the 60's of the 19th-century. Indeed, an increase in natural resources revenues (whether through the discovery of new reserves, technical improvement or the abrupt increases in the price of resources) produces a real overvaluation on the real exchange rate. As a result, the price of non-resource commodities increases, making exports costly and less competitive against the rest of the world market. Therefore, economic growth may also be negatively affected by the specialization in the natural, endogenous resources sector, flouting others, for instance, the high-tech manufacturing sector.

The natural resources' inflows also seem to create some political problems, namely: (i) corruption (Bhattacharyya & Hodler, 2014; Eregha & Mesagan, 2016); (ii) rent-seeking behavior (Mehlum & Moeme, 2006); and (iii) conflicts (Morelli & Rohner, 2015). Some resources-rich countries' show evidences that many of their the decisions are made in favor of personal benefits, where income distribution is done by powerful groups (Iimi, 2007). At meantime, the institutions play a key role for counteracting the resources curse (A. Boschini & Pettersson, 2013). In general, the resource curse literature asserts that the negative effects of the natural resource on growth are not expected in countries with high-quality institutions, already in relation to countries with weak institutions and significant corruption the possibility of a curse is expected (see for instance, Boschini & Pettersson (2013), Apergis & Payne (2014), Antonakakis, Cunado, Filis, & Gracia, (2017)).

Despite empirical evidence of the resource curse phenomenon, some studies that have analyzed countries such as Australia (Bardsley & Rogers, 2011), Botswana (Iimi, 2007), and Norway (Holden, 2013), have proven that efficient resource management policies, supported by strong institutional frameworks, promoted economic growth. Indeed, the resource curse phenomenon is far from consensual. The results may vary according to the samples, time-spans and estimations techniques, such as synthetized by Havranek, Horvath, & Zeynalov (2016). Authors found that around 40% validate the hypothesis of the resource curse, 20% find a positive effect of natural resources on growth, and thereby, they provide evidence against the resource curse hypothesis, and around 40% find no significant effect. According to this study, the lack of unanimity in the findings is mainly attributed to the choice of the natural resource type, the differentiation between the dependence and the abundance approach and, the inclusion of some control variables.

2.3 Natural gas: the debate

Overall, the literature on the resource curse phenomenon is, in part, extensive for some hydrocarbons, especially for oil, and for some mineral resources such as diamonds and precious metals. However, the effects of a natural gas abundance or dependence are less clear. Some exceptions are Stijns (2005) and Weber (2012, 2014). As already mentioned, the resource curse phenomenon is conditional to the type of natural resource studied. Fuels, for instance, are strongly and consistently related to development failures, low levels of income, corruption and rent-seeking behavior (Havranek et al., 2016). Following Boschini, Pettersson, & Roine (2007), the basic argument is that “point-source” (fuels and minerals) “are more attractive to anyone interested in short-term illegitimate gains” than the “diffuse” ones (such agriculture products). Therefore, taking into account the multiplicity of resource curse studies, mainly related to oil, what is the reason for the lack of natural gas studies? In fact, historically the natural gas abundant countries do not seem to be entirely dependent on this resource, as is observed with other resources, such oil and minerals.

Focusing on the effect of a large increase of natural gas production, Weber (2012), found that natural gas production contributes modestly to the economic activity, through the increase on total employment and total wage and salary income. The authors argued that natural gas exploitation can attract skilled workers, besides being temporary, and tax revenues can contribute to benefit the population with low taxes and more public investment. Although the modest gains, authors not discard a possible emerging resource curse phenomenon. Weber (2014), studied the impact of shale gas industry in four USA states, and not found any evidence of the resource curse phenomenon. The natural gas expansion as small effect on employment and may even increase the semi-skilled population. In fact, an increase in the quality of human capital can influence the discovery of new reserves, as well as, new ways of efficient exploitations (Stijns, 2005). Taking into account the different causal channels where the resource curse phenomenon may operate, Stijns (2005), identified positive and negative channels through which gas abundance (measured by reserves) can affect economic growth. Natural gas revenues seem to contribute positively to education, market-oriented policies and investment. Therefore, the author found some evidences of the Dutch Disease phenomenon.

Taking into consideration growing concerns about environmental damage, as well as the search for low carbon sources, natural gas provides some advantages when compared to other non-renewable energy sources. Natural gas burns more cleanly than some others fossil fuels and can be stored to meet peak demands (Destek, 2016). Also, the more recent literature highlights the potential of a complementarity between renewable energy and natural gas (Lee et al., 2012; Dong, Sun, Li, et al., 2018). The synergy between these energy sources could contribute to a reduction in CO_2 emissions (Dong, Sun, & Dong, 2018), as well as giving support to the inherent risks of intermittent generation from renewable energies by providing rapid backup (Baranes, Jacqmin, & Poudou, 2017). Also, as is pointed out by Lee et al. (2012), the volatility of gas price could be balanced out by the low and stable cost of renewable energy. Thus, any energy transition from conventional sources to renewable sources, i.e., from high-carbon to low-carbon energy, could place the "new" gas in the center of the energy mix, using it to replace the "old" fuels. In the next section the methodology used to test some of the hypotheses previously described will be presented.

3. Data and Methodology

The present section has been divided into two subsections: Data and the Method and preliminary tests. The first subsection exposes the variables used in the study, as well as the construction of the approaches that will be tested. The second subsection presented the method and some preliminary tests to understand the characteristics of both series and crosses.

3.1 Data

This study focuses on the relationship between natural gas abundance and dependence on economic growth. The main aim is to assess the presence of the "resource curse" phenomenon in this transition energy source. The countries chosen for the sample have the common characteristic of all being producers of natural gas. The annual data covers the time span from 1993 to 2015, for the twenty-five selected countries: Algeria; Arab Republic of Egypt; Argentina; Australia; Bangladesh; Canada; China; Denmark; India; Indonesia; Iran; Kazakhstan; Malaysia; Mexico; the Netherlands; Norway; Pakistan; Romania; the Russia Federation; Saudi Arabia; Thailand; Trinidad and Tobago; the Ukraine; the United Kingdom and the United States of America. The time-span and the selection of countries chosen was based on the data availability. In other words, the paper considers all the available data, both for time and countries, under the condition of it being a balanced panel; though the sample covers almost 80% of world gas production and almost 60% of world proven reserves (Statistical Review of World Energy, June 2018).

The source of the following variables was obtained from the World Development Indicators (WDI) published by the World Bank, namely: gross domestic product (constant 2010 US$); gross capital formation (constant 2010 US$); Consumer Price Index (2010 base year); trade (%GDP); unemployment (% of total labor force); labor force (total); natural gas rents (% GDP) and population (total number of persons). The data referring to natural gas production, natural gas proven reserves, natural gas prices and primary energy consumption was taken from the BP *Statistical Review of World Energy*, June 2018. All variables are in millions of tons of oil equivalent (Mtoe), except for natural gas prices, which are in constant dollars per million Btu. This variable is unique and common for all countries. The econometric analysis was carried out by using Stata software. In short, the variables used are: (i) *GDP (*Gross Domestic Product per capita); (ii) *COM (*Primary Energy Consumption *per capita)*; (iii) *GCF*

*(*Gross Capital Formation *per capita;* (iv) [1]*KOF (*KOF Globalization Index*)*; (v) *EMP* (Employment); (vi) *PROD (*Natural Gas Production *per capita);* (vii) *RES (*Natural Gas Reserves *per capita)*; (viii) *RGAS* (Natural Gas Rents *per capita*) and *POP* (total number of persons).

The *GDP per capita* is used as an economic growth proxy, as is frequently used in the literature (e.g. Sepehrdoust & Zamani Shabkhaneh, 2018). The dependent variable was obtained from the ratio between gross domestic product and total population. In order to test the traditional hypothesis of the energy-growth nexus, primary energy consumption (*COM*) was included in the study. This variable was obtained by using the ratio between primary energy consumption and total population.

The variables, Gross capital formation (*GCF*), KOF globalization index (*KOF*) and employment (*EMP*), were included as control variables. In other words, the *GCF* is incorporated to measure investment, such as, for instance by Al Mamun, Sohag, & Hassan (2017). This variable was computed as the ratio between gross capital formation and the total population. The overall *KOF Globalization* index was chosen as a measure of openness (Dreher, 2006; Marques, Fuinhas, & Marques, 2017). This index covers the economic, political and social dimension of globalization. The *EMP* variable is used as a measure of labor (Gaspar, Marques, & Fuinhas, 2017). This variable is obtained in three steps. The first step consists of dividing unemployment, as a percentage, by 100. In the second step, the former result is multiplied by the labor force, in order to obtain the absolute value. In the third step, unemployment is subtracted from labor force, in order to obtain the real value for employment.

Three approaches were computed in order to test the hypothesis of resource curse, for 25 natural gas producing countries. The production approach and the reserves approach were introduced for measuring natural gas abundance, while the rents approach was used for measuring natural gas dependence. In all three approaches, production, reserves and rents, one is looking to assess the relationship with the *GDP*, i.e., with the economic growth.

The selected variables to assess the production approach and the reserves approach are natural gas production (*PROD*) and natural gas proven reserves (*RES*), respectively. These variables were multiplied by the international price of natural gas (*GASP*) deflated by the Consumer Price Index (*CPI*), in order to obtain the real value of a country's production and reserves. The coefficient of production and reserves can be positive or negative depending on the presence of the curse.

The natural gas rents (*RGAS*) were used to assess the (economic) dependence on natural gas. The *RGAS* captures the potential value of resource production for countries, by taking the difference between the value of natural gas production at regional prices and the total costs of production (World Bank, 2018). This variable was constructed in three steps. The first step consists of dividing natural gas rents, as a percentage, by 100. In the second

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[1] This index was developed by the KOF database of the Swiss Economic Institute proposed by Dreher (2006) (Available at: http://globalization.kof.ethz.ch/).

step, the former result is multiplied by the GDP (constant 2010 US$) in order to obtain the absolute value. The final step involves dividing the above result by the total population. If, on the one hand, the signal found is positive, then there is a monetary advantage with the exploitation of natural gas. On the other hand, if natural gas rents are negative, then there is a barrier to economic growth. The negative signal could mean that there is a lack of diversification, inefficient management of natural gas revenues or rent-seeking behaviors that could lead to the resource curse phenomenon, as was discussed previously. The population was used to generate the *per capita* variables.

3.2 Method and preliminary tests

To evaluate whether natural gas abundance and dependence contributes to economic growth, and if the hypothesis of "resource course" is confirmed, the Unrestricted Error Correction Model (UECM) form of the autoregressive distributed lag (ARDL) model was applied. This model is useful when analyzing the effects both in the short- and on the long-run, and has the advantage of being able to deal with a different integration order of the variables, such I(0) and I(1). The variables are in natural logarithms, to make the non-linear relations as linear as possible. Hereafter, the prefix "L" denote natural logarithm and "D" denote first difference of the variable. The variables in their levels and in their first differences represent the long- and short-run, respectively. In such a way, the ARDL model, Eq. (1), is the following:

$$\begin{aligned} LGDP_{it} = {} & \alpha_{1i} + \varphi_{i1} D_t 2008 + \beta_{i1} LGDP_{it-1} + \beta_{i2} LGAS_{it} + \beta_{i3} LGAS_{it-1} + \beta_{i4} LCOM_{it} \\ & + \beta_{i5} LCOM_{it-1} + \beta_{i6} LGCF_{it} + \beta_{i7} LGCF_{it-1} + \beta_{i8} KOF_{it} + \beta_{i9} KOF_{it-1} \\ & + \beta_{i10} LEMP_{it} + \beta_{i11} LEMP_{it-1} + \varepsilon_{it} \end{aligned} \tag{1}$$

The *LGAS*, in Eq. (1), assume the three different approaches (production, reserves and rents approach), according to what was described in the previously section. Eq. (1) can be re-parameterized into the general UECM form, Eq. (2), in order to capture the dynamic relationship among variables, as follows:

$$\begin{aligned} DGDP_{it} = {} & \alpha_{1i} + \varphi_{i1} D_t 2008 + \beta_{i1} DLGAS_{it} + \beta_{i2} DLCOM_{it} + \beta_{i3} DLGCF_{it} + \beta_{i4} DLKOF_{it} \\ & + \beta_{i5} DLEMP_{it} + \lambda_{i1} LGDP_{it-1} + \lambda_{i2} LPROD_{it-1} + \lambda_{i3} LCOM_{it-1} \\ & + \lambda_{i4} LGCF_{it-1} + \lambda_{i5} LKOF_{it-1} + \lambda_{i6} LEMP_{it-1} + \varepsilon_{it} \end{aligned} \tag{2}$$

where α_i denotes the intercept, β_i and λ_i the estimated parameters, and ε_{it} the error term. *Dt*_denotes a dummy variable, only for production approach. The *DLGAS*, in Eq. (2), assume the three different approaches for the same propose that Eq. (1). In the production approach only, a shift dummy ($D_t 2008$) was incorporated for controlling the financial crisis in 2008, which had repercussions worldwide. The descriptive statistics for all variables can be seen in Table1, Table2 and Table3, to the production approach, reserves approach and rents approach, respectively.

Table 1. Descriptive statistics for production approach

Variables	Descriptive statistics				
	Obs	Mean	S. D.	Min.	Max.
LGDP	552	8.9997	1.4235	1.5753	11.4254
LCOM	552	-13.0539	1.1831	-16.5069	-10.9600
LGCF	552	7.5689	1.3943	4.3374	10.1289
LKOF	552	4.1339	0§.2409	3.3816	4.5024
LEMP	552	16.8472	1.5753	12.8861	20.4367
LPROD	552	-16.9287	1.7512	-21.8789	-11.1937
DLGDP	528	0.0249	0.0400	-0.2555	0.1300
DLCOM	528	0.0140	0.0492	-0.1857	0.2407
DLGCF	528	0.0272	0.1412	-0.8489	0.7055
DLKOF	528	0.0111	0.0278	-0.2122	0.1652
DLEMP	528	0.0150	0.0207	-0.1216	0.0994
DLPROD	528	-0.0523	0.4304	-3.5496	0.8653

Notes: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively; production approach register fewer observations due to the lack of data availability for Argentina.

Table 2. Descriptive statistics for reserves approach

Variables	Descriptive statistics				
	Obs	Mean	S. D.	Min.	Max.
LGDP	506	9.0650	1.4594	6.0552	11.4254
LCOM	506	-13.0804	1.2314	-16.5069	-10.9600
LGCF	506	7.6322	1.4280	4.3374	10.1289
LKOF	506	4.1473	0.2385	3.4248	4.5024
LEMP	506	16.8937	1.6303	12.8861	20.4367
LRES	506	-13.5954	2.0503	-18.0490	-7.1907
DLGDP	484	0.0255	.0342	-0.1548	0.1300
DLCOM	484	0.0167	.0450	-0.1453	0.2407
DLGCF	484	0.0297	.1284	-0.7929	0.7055
DLKOF	484	0.0097	.0265	-0.2122	0.1652
DLEMP	484	0.0167	.0196	-0.1216	0.0994
DLRES	484	-0.0742	.4008	-1.8392	1.0828

Notes: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively; reserves approach register fewer observations due to the lack of data availability for Argentina, Kazakhstan and Ukraine.

Table 3. Descriptive statistics for rents approach

Variables	Descriptive statistics				
	Obs	Mean	S. D.	Min.	Max.
LGDP	575	9.0031	1.3951	6.0552	11.4254
LCOM	575	-13.0623	1.1601	-16.5069	-10.9600
LGCF	575	7.5598	1.3674	4.3374	10.1289
LKOF	575	4.1353	0.2362	3.3816	4.5024
LEMP	575	16.8347	1.5448	12.8861	20.4367
LRGAS	575	3.2707	3.2723	-19.5866	7.8837
DLGDP	550	0.02446	0.0409	-0.2555	0.1300
DLCOM	550	0.0141	0.0485	-0.1857	0.2407

DLGCF	550	0.0264	0.1419	-0.8489	0.7055
DLKOF	550	0.0108	0.0275	-0.2122	0.1652
DLEMP	550	0.0150	0.0210	-0.1216	0.0994
DLRGAS	550	-0.0347	2.3798	-23.5219	23.5072

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

As stated before, the countries around the world chosen for the sample have the common characteristic of all being producers of natural gas. Considering that, the presence of cross-section dependence is expected and the CD-test to test for cross-sectional dependence were carried out (Table 4, Table 5 and Table 6).

The results from the CD-test strongly proved, as was expected, that cross-sectional dependence was detected for all variables. Due the presence of cross-sectional dependence, the second generation unit root tests, CIPS (Pesaran, 2007) were performed as well, to check the integration order of the variables. It is important to make sure that no I(2) variables are present. The CIPS test has as null hypothesis in the non-stationary. In contrast with the first-generation test, it has the advantage of being robust for heterogeneity. The results can be seeing in the Table 4, Table 5 and Table 6, to the production approach, reserves approach and rents approach, respectively. The CIPS test reveal that the variables are I(0) and I(1). Note that the panel ARDL approach allows the usage of variable integrated in order 0 and 1.

Table 4. Cross-sectional dependence (CD-test) and 2nd Generation Unit Root test (CIPS) for production approach

Variables	Cross-section dependence			2nd Generation panel unit root test CIPS	
	CD-test	corr	abs(corr)	No trend	Trend
LGDP	70.18***	0.881	0.881	-4.118***	-0.257
LCOM	14.71***	0.185	0.600	-3.388***	-1.525*
LGCF	39.99***	0.502	0.537	-3.499***	-1.116
LKOF	71.53***	0.898	0.898	-2.519***	-1.097
LEMP	48.02***	0.603	0.878	0.632	3.580
LPROD	44.01***	0.552	0.633	-9.789***	-10.440***
DLGDP	15.82***	0.203	0.264	-6.381***	-3.674***
DLCOM	7.02***	0.090	0.212	-13.652***	-13.087***
DLGCF	7.55***	0.097	0.248	-10.496***	-8.314***
DLKOF	16.12***	0.207	0.281	-13.233***	-11.682***
DLEMP	6.42***	0.082	0.234	-5.720***	-5.230***
DLPROD	66.38***	0.852	0.852	-12.783***	-9.819***

Notes: CD-test has N(0,1) distribution, under the H0: 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.

On the panel of the production approach, all variables are stationary in level at 1% of significance level, except the variables *LEMP*. Therefore, the cointegration test is not possible to execute. Regarding to the differentiated variables, the null hypothesis of the CIPS test is rejected at 1%.

Table 5. Cross-sectional dependence (CD-test) and 2nd Generation Unit Root test (CIPS) for reserves approach

Variables	Cross-section dependence			2nd Generation panel unit root test CIPS	
	CD-test	corr	abs(corr)	No trend	Trend
LGDP	64.90***	0.890	0.890	-1.398*	3.063
LCOM	16.07***	0.221	0.627	-2.918***	-1.442*
LGCF	38.96***	0.534	0.566	-2.923***	-0.021
LKOF	64.88***	0.890	0.890	-2.125**	-1.088
LEMP	53.87***	0.739	0.904	2.296	4.738
LRES	43.67***	0.599	0.640	-0.206	-0.382
DLGDP	14.69***	0.206	0.272	-5.271***	-3.731***
DLCOM	5.98***	0.084	0.211	-14.040***	-13.062***
DLGCF	6.47***	0.091	0.254	-9.871***	-7.792***
DLKOF	13.25***	0.186	0.267	-12.752***	-11.166***
DLEMP	7.91***	0.111	0.233	-5.292***	-4.927***
DLRES	61.22***	0.859	0.859	-9.398***	-9.049***

Notes: CD-test has N(0,1) distribution, under the H0: 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.

On the panel of the reserves approach, all variables are stationary in first differences at 1% of significance level, in other words, none of the variables are integrated of other two. In level, the *LGDP* is only stationary at 10% of significance level, *LKOF is* stationary at 5% of significant level, and the *LCOM* and *LGCF are* stationary at 1% of significance level. The *LEMP* and *LRES* are integrated of other one

Table 6. Cross-sectional dependence (CD-test) and 2nd Generation Unit Root test (CIPS) for rents approach

Variables	Cross-section dependence			2nd Generation panel unit root test CIPS	
	CD-test	corr	abs(corr)	No trend	Trend
LGDP	72.41***	0.872	0.872	-3.549***	0.463
LCOM	16.80***	0.202	0.611	-3.346***	-1.275
LGCF	41.00***	0.494	0.527	-3.231***	-0.708
LKOF	70.86***	0.853	0.853	-2.716***	-1.028
LEMP	51.14***	0.616	0.881	0.518	3.604
LRGAS	54.37***	0.655	0.762	1.357	-2.586***
DLGDP	16.85***	0.207	0.263	-6.288***	-3.655***
DLCOM	7.89***	0.097	0.213	-13.744***	-13.047***
DLGCF	8.72***	0.107	0.250	-10.380***	-8.111***
DLKOF	17.13***	0.211	0.280	-13.484***	-11.909***
DLEMP	6.80***	0.084	0.231	-6.160***	-5.699***
DLRGAS	53.04***	0.653	0.657	-11.701***	-8.914***

Notes: CD-test has N(0,1) distribution, under the H0: 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.

In the last approach, all variables are stationary in first differences at 1% of significance level. Only the *LEMP* and the *LRGAS* variables are not statistically significant in level. The other variables are stationary at 1% of significance.

Lastly, the correlation coefficients between variables and the variance inflation factor (VIF) were performed for the three approaches, in order to check for multi-collinearity among variables (see appendix A). The highest value of individual VIF is 6.94 for the independent variable energy consumption (*CONS*), and the mean VIF is 4.35, in the reserves approach. For the production approach, the mean VIF is 3.71 and for the rents approach it is 3.01. None reached the critical value of 10, in such a way that collinearity is not a concern.

Additionally, in the next section, the following will be performed: the Hausman test, some specification tests to select an robust estimator and, considering the different order of integration of the variables, the ARDL approach will be applied, and consequently the semi-elasticities and elasticities can be estimated in order to observe the short- and long-run effects, respectively.

4 Results

The present section provides the specification tests and the results for the three different approaches analyzed.

4.1 Specification tests

After checking that there are no exact linear relationships between the variables, the fixed effects (FE) were tested against random effects (RE), in order to analyze the presence of individual effects by the Hausman test. The null hypothesis states that the random effect model is the appropriate. Indeed, the Hausman´s statistically significant p-value led to the rejection of the null hypothesis, for production approach ($\chi^2 = 95.79^{***}$), reserves approach ($\chi^2 = 54.69^{***}$) and rents approach ($\chi^2 = 116.68^{***}$). In such a way, the Hausman test supports the presence of fixed effects (FE). Accordingly, there are signs of correlation between countries individual effects and the independent variables for the three approaches.

Taking into account the presence of cross section dependence and the order of integration of the series, their cointegration was tested. Thus, the Westerlund (2007) co-integration test was performed, using bootstrapping option, in order to check the presence of co-integration among the variables, for the reserves and the rents approaches, as shown in Table 7.

Table 7. Westerlund (2007) co-integration test

Statistics	Value		Z-value		P-value		Robust P-value	
Approach	RAP	RTAP	RAP	RTAP	RAP	RTAP	RAP	RTAP
Gt	-0.926	-3.077	4.447	-7.230	1.000	0.000	0.890	0.010
Ga	-2.386	-9.138	4.098	-1.833	1.000	0.033	0.940	0.051
Pt	-3.305	-6.763	3.505	-1.833	1.000	0.684	0.888	0.562
Pa	-1.802	-4.975	2.566	-0.839	0.995	0.201	0.884	0.508

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 RAP assume the reserves approach and the RTAP the rents approach.

The outcomes from the Westerlund co-integration test (Table 7) proves that the presence of co-integration is rejected, except for rents approach only to Gt and Ga statistic.

Considering that the sample cover different income levels: lower-middle-income, upper-middle-income and high-income economies, the possibility of being faced with the heterogeneous panel must be considered. In order to mislead any existence of heterogeneity between the countries, the Aggregate Mean Group (PMG) and the Mean Group (MG) estimators should be applied. The MG estimator is more flexible than PMG estimator, it produces the regressions for each individual and then it computes an average coefficient of all individuals.

The MG estimator is efficient when the long-run coefficients are heterogeneous. The PMG estimator allows the existence of heterogeneity in the coefficients of short-run and homogeneity in the coefficients of long-run. If the presence of homogeneity in the coefficients of long-run is detected, the PMG estimator is more consistent and efficient than MG estimator.

In order to test the adequacy of to use one of these models instead of another is done by performing the Hausman test once again. The null states that the difference in coefficients is not systematic. In accordance, the results of the MG and PMG estimator will be tested against the dynamic FE estimator. The FE estimator is the least flexible model, imposing the homogeneity for all coefficients. Table 8 synthetizes the results achieved for the three estimators (Aggregate Mean Group - PMG, Mean Group -MG, and Dynamic Fixed Effects -DFE estimators), as well as, the Hausman test.

Table 8. Heterogeneous estimators and Hausman test

Models	MG	PMG	FE	MG	PMG	FE	MG	PMG	FE
Approach	Production			Reserves			Rents		
Constant	0.7730	-0.1333**	1.1344***	0.2683	-0.1072**	1.1170***	2.2954	-0.0200	1.3352***
DLCOM	0.1450***	0.1406***	0.2119***	0.1371***	0.1618***	0.2153***	0.2151***	0.1986***	0.2622***
DLGCF	0.1469***	0.1356***	0.1108***	0.1569***	0 .1415***	0.1068***	0.1539***	0.1429***	0.1210***
DLKOF	-0.0225	0.0440	-0.0241	0.0006	0.1065*	-0.0374	0.1139	0.0724	0.0121
DLEMP	0.0842	0.2826**	0.2444***	0.3529**	0.2882**	0.2852***	0.0684	0.3309**	0.3186***
DLPROD	0.0144***	0.0154***	0.0238***	-	-	-	-	-	-
DLRES	-	-	-	.0100***	0.0110***	0.0145***	-	-	-
DLRGAS	-	-	-	-	-	-	0.0002	0.0039	-0.0000
ECT	-0.3087***	-0.0564***	-0.0879***	-0.3286***	-0.0574***	-0.0785***	-0.3645***	-0.0580***	-0.0951***
LCOM	-0.5610	0.2830***	0.5271***	-1.2778	0.3596***	0.5516***	2.8702	0.2240***	0.4553***
LGCF	0.3834**	0.5097***	0.3233***	0.0675	0.4975***	0.4480***	-0.9957	0.5836***	0.2578***
LKOF	1.5229	0.7378***	1.1718***	1.6613	0.6803***	0.5289**	-1.8484	0.8421***	1.5655***
LEMP	-0.2643	0.4630***	-0.2785**	0.5191	0.5057***	-0.2211*	-0.9477	.2451***	-0.4379***
LPROD	0.0346*	0.0069	-0.0331	-	-	-	-	-	-
LRES	-	-	-	0.1033	-0.0024	-0.0273	-	-	-
LRGAS	-	-	-	-	-	-	0.0131	0.0006	-0.0016
$D_t 2008$	-0.0096***	-0.0077***	-0.0092*	-	-	-	-	-	-
Hausman Tests	MG vs PMG	PMG vs FE	MG vs FE	MG vs PMG	PMG vs FE	MG vs FE	MG vs PMG	PMG vs FE	MG vs FE
Chi2(5)	8.50	0.00	0.00	6.74	0.00	0.00	2.42	0.00	0.00

Notes: ***, ** and * denote statistically significance at 1%, 5% and 10% level, respectively; ECT denotes error correction term.

The results of the Hausman test lead to rejection of the more flexible models (PMG and MG), the use of fixed effects (FE) in our estimation is the most suitable. Upon the outcomes from Table 8, a battery of specifications tests as carried out, to give some additional information for an appropriate estimator could be chosen. In order to check the presence of heteroskedasticity, the Modified Wald test was performed. Then, the contemporaneous correlation among cross-section was tested by the option of Pesaran´s test. Lastly, to check the presence of serial correlation, the Wooldridge test for autocorrelation was also computed. The specification tests' results can be seen in Table 9.

Table 9. Specification tests

	Production Approach	Reserves Approach	Rents Approach
		Statistics	
Modified Wald test	751.70***	1182.09***	2936.50***
Wooldridge test	31.501***	28.938***	36.832***
Pesaran’s test	8.574***	6.140***	6.286***

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.

As can be seen in Table 9, for the three approaches, the modified Wald test led to the rejection of the null hypothesis supporting the existence of group-wise heteroscedasticity. Following this, the rejection of the null hypothesis by the Wooldridge test prove that first-order autocorrelation was detected. Then, the results of Pesaran´s test prove the existence of contemporaneous correlation.

4.2 Results by approach

Given the presence of heteroskedasticity, contemporaneous correlation, first order autocorrelation and the cross section dependence, the Driscoll and Kray estimator was used (Driscoll & Kraay, 1998). The results of FE model, FE model with robust standard errors (FE robust), and the Driscoll and Kraay estimator (D.K.), are confronted and presented in Table 10, to the production approach, reserves approach and rents approach.

Table 10. Estimations results for production, reserves and rents approach

				Models								
	Coefficients			FE			FE Robust			D.K. FE		
Approach	PAP	RAP	RTAP	PAP	RAP	RTAP	PAP	RAP	RTAP	PAP	RAP	RTAP
Constant	1.1344	1.1170	1.3352	***	***	***	***	***	***	***	***	***
DLCOM	0.2119	0.2153	0.2622	***	***	***	***	***	***	***	***	***
DLGCF	0.1108	0.1068	0.1210	***	***	***	***	***	***	***	***	***
DLKOF	-0.0241	-0.0374	0.0121									
DLEMP	0.2444	0.2852	0.3186	***	***	***	**	*	**	***	***	***
DLPROD	0.0238	-	-	***	-	-	***	-	-	***	-	-
DLRES	-	0.0145	-	-	***	-	-	***	-	-	***	-
DLRGAS	-	-	-0.0000	-	-		-	-		-	-	
LGDP(-1)	-0.0879	-0.0785	-0.0951	***	***	***	***	***	***	***	***	***
LCOM(-1)	0.0463	0.0433	0.0433	***	***	***	***	***	***	***	***	***
LGCF(-1)	0.0284	0.0352	0.0245	***	***	***	***	***	**	***	***	**
LKOF(-1)	0.1030	0.0415	0.1489	***	*	***	**		**	***		****
LEMP(-1)	-0.0245	-0.0174	-0.0417	**	*	***			**	**	*	***
LPROD(-1)	-0.0029	-	-		-	-		-	-		-	-
LRES(-1)	-	-0.0021	-	-		-	-		-	-		-
LRGAS(-1)	-	-	-0.0002	-	-		-	-		-	-	
$D_t 2008$	-0.0092	-	-	*	-	-	**	-	-	***	-	-
Diagnostic statistics												
N				528	484	550	528	484	550	528	484	550
R^2				0.6466	0.5479	0.5882	0.6466	0.5479	0 .5882	0.6466	0.5479	0.5882
R^2 *adjusted*				0.6215	0.5158	0.5601	0.6384	0.5373	0.5797			
F				F(12,492) =75.03***	F(11,451) =49.68***	F(11,514) =66.73***	F(12,23)= 33.46***	F(11,21)= 27.32***	F(11,24)= 23.34***	F(12,21)= 93.09***	F(11,21)= 50.63***	F(11,21)= 44.88***

Notes: ***, ** and * denote statistically significance at 1%, 5% and 10% level, respectively; PAP assume the production approach, the RAP assume the reserves approach and the RTAP the rents approach.

Regarding the semi-elasticities and the elasticities, Table 11, displays the short- and long-run impacts/elasticities for the production approach. The production approach was performed to understand how natural gas abundance affects the economic growth, as well as some drivers of the economic growth. Note that the long-run elasticities are not directly provided by estimates, contrary to the short-run semi-elasticities. The elasticities were obtained by dividing the coefficient of the variables by the coefficient of *LGDP*, both lagged once and multiplied the ratio by -1.

Table 11. Elasticities, semi-elasticities, impacts, and adjustment speed for the production approach

Models	Coefficients	FE	FE Robust	FE D.K.
Short-run elasticities		Significance level		
Constant	1.1344	***	***	***
DLCOM	0.2119	***	***	***
DLGCF	0.1108	***	***	***
DLEMP	0.2443	***	**	***
DLPROD	0.0238	***	***	***
Long-run elasticities				
LCOM(-1)	0.5271	***	***	***
LGCF(-1)	0.3233	***	***	***
LKOF(-1)	1.1718	***	***	***
LEMP(-1)	-0.2785	**		**
LPROD(-1)	-0.0331			
$D_t 2008$	-0.0092	*	**	***
Speed of adjustment				
ECT	-0.0879	***	***	***

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

On Table 11, it can be seen that natural gas production has a positive effect on economic growth. The *KOF* variable is not statistically significant in the short-run, as well as *PROD* variable in the long-run. Despite the parsimonious principle, the variable *PROD* was maintained in Table 8 to facilitate the comparison to the others approaches. It is worthwhile to note that the Russian crisis and the Indonesian crisis are captured by the variable $D_t 2008$

Table 12 synthetizes the short-run semi-elasticities/impacts and the long-run elasticities/impacts for the models FE, FE robust and the FE D.K., for the reserves approach. The reserves approach show how natural gas proven reserves affect economic growth as well as some drivers of the economic growth. This reserves approach is alternative to the production approach (Table 11) with the same purpose of understanding the role of gas abundance in growth.

Table 12. Elasticities, semi-elasticities, impacts, and adjustment speed for the reserves approach

Models	Coefficients	FE	FE Robust	FE D.K.
Short-run elasticities		Significance level		
Constant	1.1170	***	***	***
DLCOM	0.2153	***	***	***
DLGCF	0.1068	***	***	***
DLEMP	0.2852	***	*	***
DLRES	0.0145	***	***	***
Long-run elasticities				
LCOM(-1)	0.5516	***	***	***
LGCF(-1)	0.4480	***	***	***
LKOF(-1)	0.5289	**		*
LEMP(-1)	-0.2211	*		**
LRES(-1)	-0.0273			
Speed of adjustment				
ECT	-0.0785	***	***	***

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

On Table 12, one can observe that the natural gas proven reserves have a positive effect on economic growth in short-run. This result is consistent with the production approach (Table 11), natural gas abundance seams to promote economic growth. The *KOF* variable is not significant in both the short- and long-run, as well as *RES* in long-run. For the same propose that in production approach, the natural gas proven reserves were kept in Table 12.

The outcomes for the rents approach are displayed on Table 13. This approach is computed to understand the role of natural gas rents on economic growth, i.e., the economic dependence from natural gas, including the same control variables presented in the other two approaches.

Table 13. Elasticities, semi-elasticities, impacts, and adjustment speed for the rents approach

Models	Coefficients	FE	FE Robust	FE D.K.
Short-run elasticities		Significance level		
Constant	1.3352	***	***	***
DLCOM	0.2622	***	***	***
DLGCF	0.1210	***	***	***
DLEMP	0.3186	***	**	***
DLRGAS	-0.0000			
Long-run elasticities				
LCOM(-1)	0.4553	***	***	***
LGCF(-1)	0.2578	***	**	***
LKOF(-1)	1.5655	***	***	***
LEMP(-1)	-0.4379	***	**	***
LRGAS(-1)	-0.0016			
Speed of adjustment				
ECT	-0.0951	***	***	***

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

Regarding the rents approach on Table 13, the variable natural gas rents (*RGAS*) are not statistically significant, both in the short- and long-run, as well as *KOF* variable in short-run.

Considering the outcomes of the Tables 11, 12 and 13, the variable *EMP* deserves special attention. In the three approaches, the effect from *EMP* on the economic growth, in the short- run, is positive as expected. However, in the long- run, an increase of 1% in *EMP*, decrease economic growth by around 0.28, 0.22, 0.44 in production approach, reserves approach and rents approach, respectively. This result will be properly discussed in the next section.

The long-run dynamics displayed by the error correction term (ECT) is negative and highly statistically significant, for all three approaches. This means that, the results are consistent with the presence of long memory between economic growth and the variables. Thus, all variables are responsible for certain changes on economic growth in the long-run. However, the speed of adjustment is low a moderate, revealing that shocks require a longer adjustment time to return to equilibrium. This result is not uncommon given that the adjustment of energy structures are long processes and require an extensive period of adjustment (see for instance Apergis & Payne (2010a)). Comparing the three approaches the reserves approach takes more time to return to the equilibrium.

5. Discussion

Looking to understand the effect of natural gas abundance and dependence on economic growth, three different approaches were applied in this paper to test the "resource curse" hypothesis. The focus on natural gas as an energy source is of particular relevance, not only due to the scarce literature regarding this fossil fuel, but essentially due to it being a transition source, which is able to backup intermittent renewables. The scale of using natural gas has been growing and, as such, the main question is to know if the resource curse, often observed in other fossil sources, could also be observed with natural gas. Has there been a learning effect, and are the countries abundant in natural gas therefore now able to avoid the curse?

In order to assess the effect of natural gas abundance on economic growth, two alternative approaches were employed in the study, namely the production approach and the reserves approach. Moreover, another approach, the natural gas rents approach, was used to assess the relationship between natural gas dependence and economic growth. As such, and in order to meet the objective of this paper, these three approaches were confronted.

The "resource curse" hypothesis is not verified. Note that the empirical evidence of the relationship between abundance or dependence on natural gas and economic growth are scarce in the literature. Some findings have to be compared with other studies that takes into account other kinds of natural resources, such as oil or minerals. On the contrary, the findings from the production approach, prove that natural gas production promotes economic growth. This result is consistent with Songur, Muratoğlu, & Muratoğlu (2016). Considering the self-sufficiency ratio, it was verified that most of the countries are net exporters. For example, Algeria, Norway and Russia are the main suppliers of Europe. In contrast, the United States of America is one of the largest producers of natural gas, but its use is mainly concerned with meeting the needs of its high domestic demand. The tax revenues from natural gas production could benefit governments and the population in general through efficient public investment, income distribution, and poverty reduction, among others.

The alternative approach proves that gas reserves promote economic growth. The reserves generate a comparative advantage for countries, and some expectations that can be used in the future. The increasing demand for energy, and especially for more clean energy, puts abundant countries in a good position to export, and to benefit from natural gas revenues.

Regarding the dependence approach, the resource curse hypothesis was not verified. Natural gas rents reveal no significance, neither in the short- or in the long-run. On the one hand, natural gas rents might not be enough to capture the dependence effect of natural gas. On the other hand, the finding may suggest that the sample countries may be taking this revenue as a way of diversifying the productive structure. It is worthwhile to note that for resource rich countries, diversification is fundamental to avoid phenomena such as the Dutch Disease, and consequentially the phenomenon of the “resource curse”. Also, in the worst case scenario, the presence of rent-seeking behavior by the private companies for management of natural resources could be another reason for the non significance of natural gas rents on economic growth, such as was found by Al Mamun et al. (2017) for the oil case.

Some drivers of economic growth were also detected, such as capital and globalization. With similar effects observed in the three approaches, employment promotes economic growth, in the short-run such, as Gaspar et al. (2017) observed, however, in the long-run, employment has a negative effect on economic growth. In the first instance, this negative relationship was unexpected, even more so because natural gas exploration tends to attract workers, even if they are of a temporary nature (Weber, 2014). However, while it may be unexpected, this negative effect has already been detected in the literature, for instance by Al Mamun et al., (2017). It can be explained by the fact that natural resources, such as natural gas and oil, need to be extracted and do not need to be produced. The extraction of these resources is essentially capital intensive. Thus, the resource sector is associated with low employment and the “skills required for the jobs do not fit in the profile of a country's unemployed” (Badeeb et al., 2017), regarding the capital invested. An increase of capital intensity generally requires a skilled labor force and training to operate. If the quality of the workers does not fit into the profile of this intensive industry, then the impact on the economy could be damaging. This negative effect can be also be a kind of residual evidence for the Dutch Disease model. The explanation could be related to the resource movement effect. Natural resource specialization increases the demand for labor and other production inputs, which are destined towards the resource sector, and away from the manufacturing or agriculture sectors. In other words, this generate a loss of participation in the non-resource sector, in both product and employment generation. In the context of policy implications, increasing the share of investment in education should be a priority for the governments of these natural gas abundant countries. The rational allocation of natural gas revenues could create conditions to increase human capital accumulation by ensuring quality education and support for the skilled labor of the future. This recommendation is also backed up by Shahbaz, Akif, Okumus, & Sinha (2019), which point out that an increase of human capital accumulation may be necessary to avoid the resource curse phenomenon.

The abundant countries can benefit from globalization, through the facility in the expansion of trade and foreign direct investment, for example. For these natural gas producers, globalization has a positive effect on growth. The elasticity of more than one may not seem very usual, but resource-rich countries are highly influenced by the external market, as they earn excessive foreign exchange through trade. Furthermore, the geographic separation between supply and demand for natural gas implies the exposure of natural gas producing countries to the global market (Kan, Chen, Wu, Chen, & Chen, 2019). Through globalization, countries can also transfer efficient technologies and technical knowledge for an efficient use of energy. Evidence was found, in both the short- and the long-run, of the traditional growth hypothesis. There is a unidirectional causality running from energy consumption to growth. This result is reinforced by the rejection of the resource curse hypothesis. The usual implication of the growth hypothesis suggests that conservation energy policies may adversely affect economic growth. In such a way, policymakers should be aware of the policies adopted to avoid any slowdown in economic growth.

The “resource curse” hypothesis is not validated in any of the three approaches. On the one hand, natural gas abundance seems to promote economic growth. On the other hand, natural gas dependence shows no effect both in the short- and the long-run. Some empirical resource curse studies found evidence that resource dependence is related to the resource curse phenomenon rather than to a country´s possession of natural resources, i.e., natural resource abundance (Gylfason & Zoega, 2006; Shahbaz et al., 2019). If the selected countries were truly economically dependent on the revenue generated by the natural gas industry, as some economies are of oil, maybe the outcomes would be different. Indeed, the enlargement of the scale of use of this source could provoke dissimilar effects, namely on the resource curse. Also, the global natural gas market is becoming extremely increasingly accessible across the world, connected by pipelines and shipping. In this condition, the future development of natural gas will change the energy structure of these countries by promising to overtake oil as the dominant fossil fuel in the foreseeable future. In this way, investments in reclassifying and increasing the infrastructures of natural gas must be considered, as well as, some strategic planning to meet the growing use of this source.

More and more countries are committed to a diversification of their energy mix, while at the same time trying to fight against climatic changes. Overall, this paper’s findings support that natural gas could be a milestone in terms of the fossil sources, not only due to its properties as a cleaner, controllable energy source, but also for the consciences of using that source carefully, thus avoiding creating excessive dependence on it within national economies. All evidence points to natural gas being the most suitable fuel for electrical generation, not as a baseload generation source, but as a backup for intermittent renewables. Moreover, contrarily to other fossil sources, namely oil, natural gas has not been used in a large scale in the transport sector. Moving forwards, policymakers need to think about how they can modernize their use of energy resources, especially when faced with an abundance of natural gas reserves. They need to develop policies which lessen the dependence on traditional fossil fuel resources, like oil, and the revenues they generate. In the meantime, they should make sure that their countries are able to diversify their own energy mix, given that most of recent technologies that these countries receive are more electricity intensive.

6. Conclusion

This paper focuses on the analysis of the relationship between natural gas abundance and dependence on economic growth. Based on a sample of natural gas producing countries, the use of macro panel data, with 23 years and 25 countries assures robustness to analysis. Overall, the results prove that natural gas abundance promote economic growth. This finding is of particular relevance for the extensive literature on resource curse. This means that the resource curse hypothesis is not verified to the natural gas source. In fact, the possession of natural gas seems to increase growth, while the dependence can be relatively small component of overall output and has no impact on growth.

In addition to being extremely important in understanding how dependence on, or abundance of natural gas can affect economic growth, it is also essential to understand how these abundant countries can use this energy source to achieve long-term sustainable development. Stabilizing an appropriate legal framework, ensuring anticorruption policies are in place, and making sure that transparency is present in resource management, are important prerequisites so as not to fall into the trap of the resource curse phenomenon. Consequently, in order to achieve long-term development of the natural gas industry, human capital development and the efficient investment in infrastructure are necessary. In conclusion, the results suggest that the effects of the resource curse have not been verified for the natural gas case. In fact, it seems that the curse is related to the high dependency on one or two types of natural resources, instead of the possession of natural resources.

This study uses the *GDP* per capita to measure economic growth, as is common in literature, however, the *GDP* does not take into consideration environmental issues or social welfare. In this way, for future research, the insertion of a development indicator, such the Human Development Index (composite index of life expectancy, education and GDP *per capita),* could provide useful additional information, when compared to the *GDP* outcomes.

Appendix

Table A.1 – Table A.3

Table A.1– Matrices of correlation and VIF statistics for production approach

	LGDP	*LCOM*	*LGCF*	*LKOF*	*LEMP*	*LPROD*
LGDP	1.0000					
LCOM	0.8723	1.0000				
LGCF	0.9788	0.8577	1.0000			
LKOF	0.8046	0.6532	0.7732	1.0000		
LEMP	-0.4779	-0.5205	-0.4187	-0.2664	1.0000	
LPROD	0.6214	0.7383	0.5822	0.3719	-0.6806	1.0000
VIF		5.64	5.41	2.56	1.87	3.10
Mean VIF	3.71					

	DLGDP	*DLCOM*	*DLGCF*	*DLKOF*	*DLEMP*	*DLPROD*
DGDP	1.0000					
DCOM	0.5440	1.0000				
DGCF	0.5440	0.3285	1.0000			
DKOF	-0.0007	-0.0012	-0.0286	1.0000		
DEMP	0.2305	0.3166	0.2149	0.0086	1.0000	
DPROD	0.4650	0.3137	0.2066	0.0023	0.2549	1.0000
VIF		1.27	1.15	1.00	1.16	1.15
Mean VIF	1.15					

Table A.2 – Matrices of correlation and VIF statistics for reserves approach

	LGDP	*LCOM*	*LGCF*	*LKOF*	*LEMP*	*LRES*
LGDP	1.0000					
LCOM	0.9013	1.0000				
LGCF	0.9801	0.8856	1.0000			
LKOF	0.8395	0.7085	0.8032	1.0000		
LEMP	-0.4979	-0.5190	-0.4400	-0.3184	1.0000	
LRES	0.4272	0.5991	0.4231	0.1267	-0.6212	1.0000
VIF		6.94	6.51	3.70	1.80	2.82
Mean VIF	4.35					

	DLGDP	*DLCOM*	*DLGCF*	*DLKOF*	*DLEMP*	*DLRES*
DGDP	1.0000					
DCOM	0.4974	1.0000				
DGCF	0.5375	0.2535	1.0000			
DKOF	0.0584	0.0584	-0.0100	1.0000		
DEMP	0.1610	0.2451	0.1724	0.1116	1.0000	
DLRES	0.3064	0.1733	0.1613	0.1105	0.1541	1.0000
VIF		1.13	1.10	1.02	1.10	1.07
Mean VIF	1.09					

Table A.3 – Matrices of correlation and VIF statistics for rents approach

	LGDP	*LCOM*	*LGCF*	*LKOF*	*LEMP*	*LRGAS*
LGDP	1.0000					
LCOM	0.8712	1.0000				
LGCF	0.9776	0.8577	1.0000			
LKOF	0.8042	0.6512	0.7708	1.0000		
LEMP	-0.4776	-0.5178	-0.4163	-0.2671	1.0000	
LRGAS	0.3251	0.3753	0.3083	0.2423	-0.4444	1.0000
VIF		4.35	5.38	2.49	1.54	1.30
Mean VIF	3.01					

	DLGDP	*DLCOM*	*DLGCF*	*DLKOF*	*DLEMP*	DLRGAS
DGDP	1.0000					
DCOM	0.5448	1.0000				
DGCF	0.6055	0.3379	1.0000			
DKOF	0.0042	0.0006	-0.0237	1.0000		
DEMP	0.2630	0.3160	0.2434	0.0042	1.0000	
DLRGAS	0.0509	0.0511	0.0360	0.0459	0.0393	1.0000
VIF		1.21	1.16	1.00	1.14	1.01
Mean VIF	1.10					

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