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A road to enhancements in natural gas use in Iran: A multivariate modelling approach

Daniel Balsalobre-Lorente[a,*], Festus Victor Bekun[d,e], Mfonobong Udom Etokakpan[b], Oana M. Driha[c]

[a] University of Castilla-La Mancha, Department of Political Economy and Public Finance, Economics and Business Statistics and Economic Policy, Spain
[b] Department of Economics, Famagusta, Eastern Mediterranean University, and North Cyprus, Via Mersin 10, Turkey
[c] Department of Applied Economics, International Economy Institute.University of Alicante, Spain
[d] Faculty of Economics Administrative and Social sciences, Istanbul Gelisim University, Istanbul, Turkey
[e] Department of Accounting, Analysis and Audit, School of Economics and Management, South Ural State University, 76, Lenin Aven.,Chelyabinsk, Russia 454080

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ABSTRACT

The primary focus of this study is to empirically investigate the natural gas consumption-economic growth nexus in Iran, while incorporating real gross fixed capital formation (GFCF) and the role of oil revenue (OR) as additional variables to make it a multivariate framework in order to avoid possible omission variable bias in the estimations. To this end, quarterly frequency data from 1990Q1 to 2017Q4. Structural break point unit root test like Zivot and Andrews is employed and complemented with traditional non-stationarity tests such as Augmented Dickey Fuller and Phillips and Perron unit tests to investigate the interest variables stationarity characteristics. Recently developed Bayer and Hanck (2013) combined cointegration test is used alongside the Pesaran et al. (2001) bounds testing cointegration to test for long-run relationship among the variables. Finally, we test for causal relationships through Modified Wald test of Tada-Yamamoto (1995) Granger causality tests is employed. Empirical findings show cointegration relationship between the variables while accounting for structural break. Further piece of empirical results suggest that natural gas consumption exerts a significant positive impact on economic output in Iran, and also that there is a one-way causality from natural gas consumption to economic output. Thus, our study corroborates the natural gas-led growth hypothesis; being natural gas consumption a suitable alternative, as a complementary green energy source (IGU, 2015). One important conclusion reached in our study is that there is need for energy portfolio diversification in Iran in order to attain full gains from the energy sector, reducing other energies' emissions. Further insights are elucidated in the main text. Our findings provide policymakers useful insight into the state of the energy sector in Iran.

1. Introduction

The importance of energy consumption to the growth of the economy in the last two or three decades has been strongly recognition not only by the economists but by policymakers, engineers, businessmen, government and energy agencies. As outlined by the United States Energy Information Administration (EIA) (EIA, 2018), that there is a connection between country's economy and its energy consumption. The demand for energy consumption has increase swiftly, mostly for natural gas and oil, this is as a result of rapid increase in economic growth across the globe. Furthermore, the causal link between natural gas consumption (NGC) and economic growth has been an interest point for many researchers (Lee and Chang, 2005; Zamani, 2007; Isik, 2010 or Solarin and Shahbaz, 2015, among others).

Natural gas (NG hereafter) is an alternative non-renewable energy source that boost economic activities in nations endowed with huge deposit either developed, developing and emerging economics (Apergis and Payne, 2010). NG a form of hydrocarbon gas element occurs naturally, consisting primarily of methane, generally, NG most frequently constitute varying amounts of other higher alkanes sometimes a small fraction of carbon dioxide, nitrogen, hydrogen sulfide, or helium. In the face of continuous decline in oil reserves in most oil producing economies, NG has been identified as a suitable alternative as it produces 30% less carbon dioxide than crude oil and 45% less than burning coal. According to the studies conducted by Shahbaz et al. (2013a, b) and Apergis and Payne (2010) posited that NG can take over the

* Corresponding author.
E-mail addresses: daniel.balsalobre@uclm.es (D. Balsalobre-Lorente), festus.bekun@emu.edu.tr (F.V. Bekun), etokakpanmfonudom@yahoo.com (M.U. Etokakpan), oana.driha@ua.es (O.M. Driha).

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important role of crude oil in the economic growth process, if due attention is given. Empirical studies on the theme describe NG as an essential non-renewable energy source which can be harnessed to boost economic activities irrespective of the level of development of such economies. On this premise, a need to revisit the energy-growth nexus with NG as the central focus arises. The present study focuses on industrial natural gas consumption (NGC) rather than household sector consumption for Iran. The study adopts the use of recent econometric techniques. This will be of great use to stakeholders and policymakers that design and formulate energy strategies/laws.

The choice of Iran as a case study is due to her large NG output and consumption. Iran is one of the largest net-exporters of hydrocarbon products. The country not only hosts the world's second largest NG reserves after Russia but also is the fourth largest producer of NG in the world. Recent statistics from the Iranian Petroleum Ministry reveals that 16% of the world's reserves of NG is deposited in Iran. 33% of these reserves are associated NG while the remaining 67% are non-associated (Iran Oil Ministry Annual Bulletin, 5th edition). In 2010, Iran's NG net export was about 1.57 billion m^3, with its NG production valued at 138.5 billion m^3. In the same period, the total imports cost 6.85 billion whereas exports stood at 8.42 billion m^3, the key trade partners being Turkey, Azerbaijan, Turkmenistan and Armenia. Figs. 1–3 provides the schematic of the dynamic of natural gas dynamics. For instance, Fig. 1 shows the persistent trend in the last 2-3 decades of production and consumption of natural gas. Subsequently Figs. 2 and 3 also renders a pictorial display of top natural gas flaring nations in the world and net trading partners with Iran.

The adoption of NG as a feasible alternative to other fossils fuels has resulted in an increase in Iran's domestic consumption of NG. This increment is also noticeable in exports as the country's NG exports increased by five-fold to 60 billion m^3 by 2014 as outlined by Iran Oil Ministry Annual Bulletin, 5th edition. This increase in NG consumption is a result of the combination of the following factors: reduction in the domestic supply price of NG, wasting energy technologies, inappropriate and abundant use of NG. This consumption situation raises certain issues; on one hand, one may assume that increased NG consumption will produce a cleaner environment and birth economic prosperity, while on the other hand however, numerous researchers have suggested that in general, resource extraction often crowds out other economic activities, especially manufacturing, and reduces the growth impact of other sectors of the economy (Mankiw et al., 1992; Sachs and Warner, 2001). The above assertion is known as Dutch disease hypothesis. Thus, it pertinent to examine how NG affects the economic growth of Iran. Also, while NG demand may be able to affect economic growth, economic growth may also have effect on NG demand, as the strength of an economy can influence the energy market. For example, during periods of boom, increases in demand for goods and services may cause increases in NG consumption. Thus, the need to underpin the directional causality flow between NG consumption-

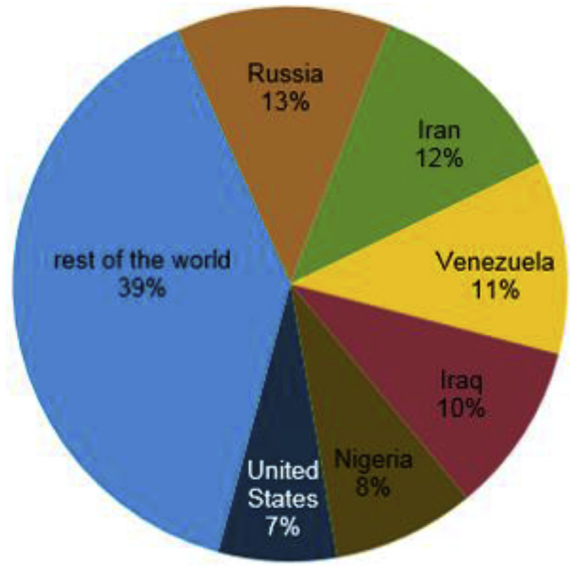

Fig. 2. Top natural gas flaring countries
Source: U.S. Energy Information Administration, based on OPEC Annual Statistical Bulletin (2015)

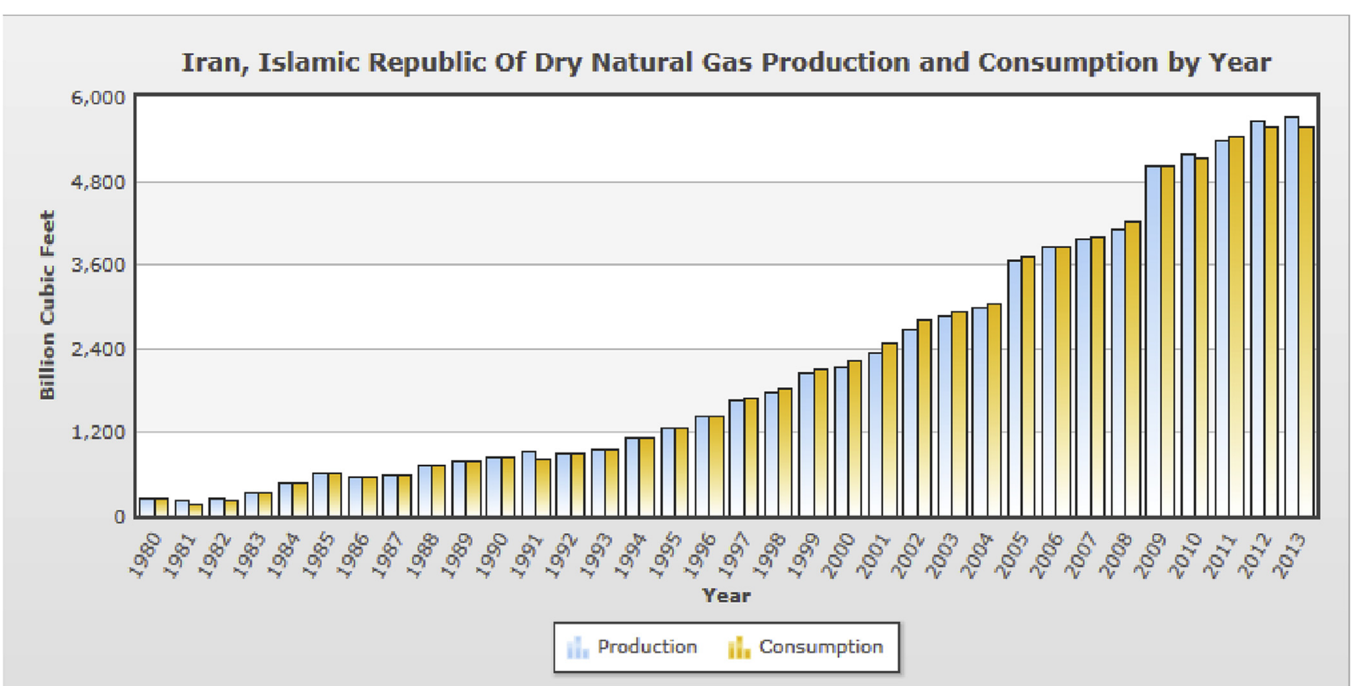

Fig. 1. Iran Dry natural gas production and consumption
Source: United States Energy Information Administration (2018)

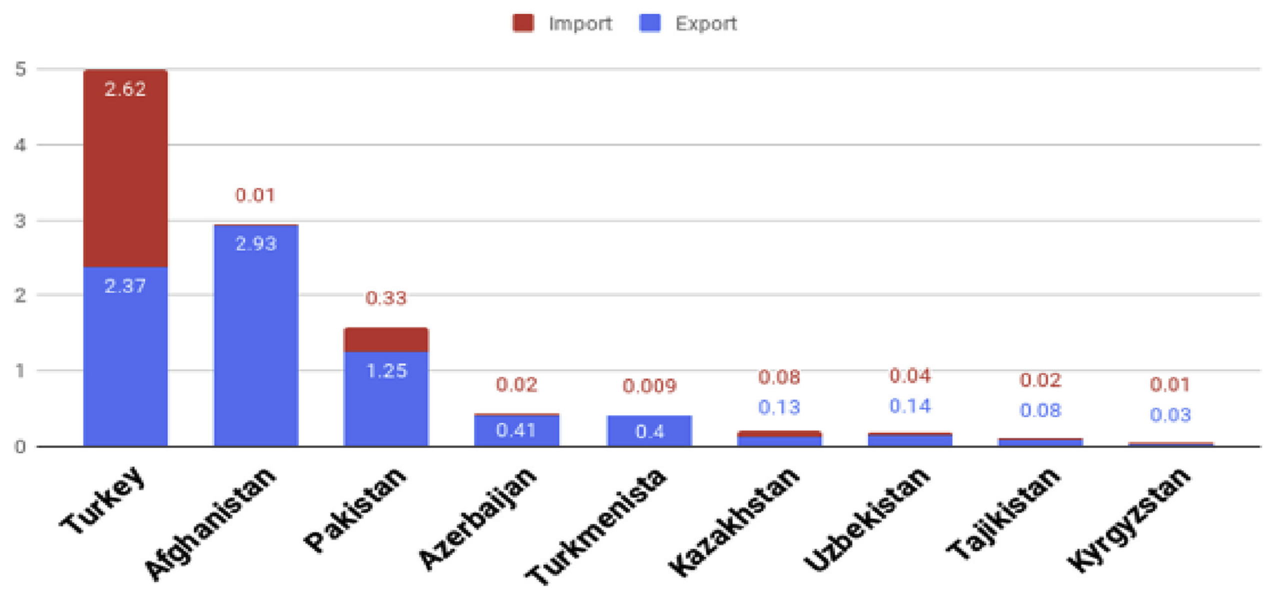

Fig. 3. Top trading natural gas importing and exporting countries with Iran
Source: IEA (2018)

economic outputs is pertinent and timely.

Recently, there has been growing interest in examining the linkage between economic growth and NG consumption. Studies on this issue have however produced contradictory empirical outcomes. These contradictions in extant literature may be as a result of the bivariate econometric frameworks mostly adopted in past studies. A major flaw of bivariate models is that they suffer from omitted variable bias (model misspecification) and for this reason, their estimation outcomes are spurious. The implication is that the policy implications from such studies are unreliable (Dolado and Lutkepohl, 1996). There is thus a need to incorporate additional important variables with relatively high explanatory powers. Hence, scholars such as (*interalia* Apergis and Payne, 2010; Kum et al., 2012), among others have studied the theme under consideration in multivariate framework using diverse econometric approaches.

Against the above highlighted premise that this study explores the interaction between consumption of natural gas-economic growth nexus by extending the bi-variate framework by incorporation of important variable to make multivariate. The addition of our study to the frontiers of knowledge is in four-fold; (i) In terms of scope, we augment the NG-economic growth nexus with real gross fixed capital formation (GFCF) to ascertain the role of capital in economic output and also with oil rent seeking for Iran given the pivotal role oil plays in Iranian economy an area which has not been properly documented in the literature. Also, the present study also explore the role of non-oil GDP on NG consumption in Iran economic output given the peculiarity of our case study. The Iranian economy has suffered from war and western sanction before the 1990s so it pertinent to see if such episodes plays out on the current empirical discourse (Amadeh et al., 2009; Hafeznia et al., 2017; Akadiri and Akadiri, 2018). (ii) In terms of methodological advancement, because most economic and financial datasets are plagued with possible break dates we account for structural break in our econometric analysis. The need to account for possible break(s) dates are pertinent, otherwise obtain coefficient estimates will be inconsistent and unreliable for policy analysis. (iii) This study applies estimation techniques such as Zivot and Andrews (1992) unit root to detect the unit root/stationarity traits of variables under consideration. (iv) For cointegration relationship, we utilize Pesaran's auto regressive distributive lag (ARDL) methodology and the newly advanced Bayer and Hanck (2013) combined cointegration test as complementary to Pesaran's test while we apply Toda-Yamamoto-Granger causality test (1995) a modified Wald methodology (MWALD) which is known to render more robust results than the conventional Granger causality test is adopted to detect the direction of causality to explore the causality flows between the variables under review.

The rest of the current study proceeds as; section-2 provides a brief review related studies on NG-economic growth. Section-3 dwells on the methodological construction and data while section-4 concentrates on empirical findings and discussion. Finally, the study summary (conclusions) and possible policy direction are rendered in section-5.

2. Theoretical background

A few theoretical studies have been documented formally that model a direct connection between energy and economic growth, energy and environment. The extant empirical literature on the theme cut across single country, cross country and panel analysis. We set off by briefly discussing the theoretical foundation. Subsequently, empirical studies that outline the transmission mechanism that explains the energy-income nexus. For this particular study, the incorporation of oil rent and capital to economic growth is explained.

The quest for economic growth seems the most pertinent issues for most if not all economies across the globe. Thus, the need to identify growth indicators is key for government administrators and policymakers. There exist a large body of theoretical studies on the economic growth, majority rely on the well-known Solow growth model. The Solow growth model outlined that a substantial level of labour and capital accumulation with right level of technology known as the "*Slow residual*" explains economic growth. Over the years the conventional Solow growth model has been augmented with other variables like energy use, tourism, population and other demographic indicators (Soytas and Sari, 2009).

The study of Kraft and Kraft (1978) empirically serves as the bedrock in energy literature when considering the relationship between income and energy consumption. The study serves as an invitation to several other studies in the energy economics literature. It is from Kraft and Kraft A, 1978 that this study establishes an interaction between economic growth and energy consumption for the United State. Further motivation for this present study is hinge on the theoretical framework developed by (Dietz and Rosa, 1994; York et al., 2004) popularly referred to as Stochastic Impacts by Regression on population, Affluence, and Technology (STIRPAT).

Iran being a world leader in the NG exportation and major consumer domestically, with lot of revenues derived from NG can lead to an increase in accumulation of foreign exchange reserves. Where there is a considerable improvement in the terms of trade, this will have a ripple effect on the appreciation of the real exchange rate. This will also translate in the short run to economic growth.

The transmitting mechanism by which energy consumption translates into economic growth is seen from the accrual from the revenues generated from the proceeds of NG consumption. Increase from this revenue is used both for investment in the public infrastructure architecture as well as consumption. In the work of Basher and Fachin (2013), long run interaction is established to exist between savings and investment. In recent times, there been a drift from household consumption to the industrial sector given the adoption of new technologies for exploration and exploitation of NG. These new technologies in form of high efficiency low emission (HELE) approach will increase the industrial consumption of NG in Iran in the coming years. More so, government intervention in terms of pipeline installation and subsidies has also encourage private sector investment in no more measure. This finding helps to relax the constrain of low domestic savings which is usually encountered by private investment, so higher income from the NG revenues induces higher savings thereby increase in investment and accumulation of capital which is key in expanding the economic activities in the domestic economy (Ramey, 2011; Esfahani and Yousefi, 2017).

Numerous studies in recent years investigating the relationship between energy consumption (including both renewable and nonrenewable sources) and economic growth abound in the energy literature. Payne (2010) and Ozturk (2010) in their comprehensive review of various literatures on NG and economic growth nexus basically summarized four hypotheses that are testable.[1]

There are limited papers in the literature with regard to causal relationship between NG consumption and economic growth. This review will explore it categorically to ascertain the extent to which gap exist. First category explores studies that have deduce causality between these variables using cointegration technique. Second category considers bivariate studies which have employed causality tests. Third category explores the trivariate approach while still employing the causality tests. The last category while building on the shortfalls of previous categories, uses multivariate series to implement the causality tests. Beginning with the first category, Lee and Chang (2005) studies have applied the cointegration techniques to examine the relationship between NG and economic growth. These studies used Johansen (1988), Hansen (1992), and Gregory and Hansen (1996) test of cointegration to examine for the period 1954–2003 relationship between NG consumption and economic growth. The test results revealed causality flow from NG consumption to real GDP using the weak exogeneity as a notion of long run causality in a cointegration system.

According to Zamani (2007) investigated the relationship between the Iranian economy and NG consumption covering the period from 1967 to 2003. Evidence from the studies showed bidirectional relationship between NG consumption and GDP. Similar studies in Taiwan was conducted by Hu and Lin (2008) using Hansen and Seo (2002) cointegration test to investigate the relationship between real GDP and NG consumption. The result supported and confirmed feedback hypothesis for Taiwan. In Pakistan for the period 1972–2007, Khan and Ahmad (2008) used Johansen (1988) along with Johansen and Juselius (1990) tests to examine the relationship NG consumption per capita, gas price and real GDP per capita. Conservative hypothesis was ascertained and confirmed from the analysis. Isik (2010) investigated the relationship between NG consumption and economic growth for the period span of 1977–2008 in Turkey. The result showed a positive influence of NG consumption by the economic growth in the short run whereas in the long run negative relationship was observed. Considering various reviews made by scholars as contribution to the body of knowledge on this subject, there seem to be a major weakness of applying cointegration tests to determine causality direction without including Granger causality formally. Nevertheless, cointegration existence does not necessarily specify causality direction.

Certain bivariate studies have applied series of causality tests to deduce that there exists causal relationship between NG consumption and economic growth. Yu and Choi (1985) in attempt to determine the direction of causality in UK, US and Poland deployed Sims (1972) and the result showed causality flowing economic output (GDP) towards NG consumption, whereas in the case of US and Poland there was no causality established among the variables. Investigating the relationship between NG consumption and economic growth in Pakistan drove Siddiqui (2004) to use Hsiao (1981) for the period span 1970–2003. No causality was found among the variables as revealed by the results. A case of single causality was observed to be flowing from NG consumption to economic output as investigated by Yang (2000) in his studies seeking to establish causality between utilization of gas and economic growth in Taiwan for the period of 1954–1997.

Adeniran (2009) deployed Sims (1972) tests of causality to investigate the causal relationship in Nigeria from 1980 to 2006. Causality was observed from the results to flow from the real GDP to NG consumption.

Furthermore, Payne (2010) for the period 1949–2006 in the US. The study investigated causal relationship between economic growth and NG consumption. Positive causality that is a directional causality flowing from economic growth towards NG consumption was the outcome of study. Also, in a different bivariate study by Zahid (2008), where three countries (India, Bangladesh and Pakistan) where investigated with regards to causality relationship from 1971 to 2003. One direction causality flowing from NG consumption was observed from the results to the economy in Bangladesh, whereas no causality was demonstrated for India and Pakistan. Lim and Yoo (2012) using quarterly data from 1991 to 2008 examined causal relationship between NG consumption and economic growth in Korea for both short and long run. Evidence of double-sided Granger causality was reported from the result between NG consumption and economic growth. Das et al. (2013) examined the interaction or association existing between NG consumption and economic growth from 1980 to 2010 in Bangladesh. Results from this study established that NG consumption flow to real GDP in the long run and it is one way with Granger causality test. Similar study by Bildirici and Bakirtas (2014) explored the relationship between economic growth and NG consumption among the various types of energy available for countries including Russia, Turkey and Brazil. Evidence from the tests result showed feedback causality relationships between economic growth and NG consumption for the countries under study. Pirlogea and Cicea (2012) also considered the causal relationship between NG consumption and economic growth per capita for the period 1990–2010 in Romania and Spain. Evidence from test results using Granger (1969) revealed causal relationship flowing from NG consumption towards economic growth in Spain, whereas in Romania there was no causal relationship established.

More recently, Solarin and Ozturk (2016) assessed the causal relationship between NG consumption and economic growth in a panel of OPEC members, and their findings revealed a feedback relationship. However, evidence obtained when member countries were examined individually was different. There was evidence of growth hypothesis in countries like Iraq, Kuwait, Nigeria and Saudi Arabia, whereas the conservative hypothesis held in other member countries like Algeria, Iran, the United Arab Emirates and Venezuela. Furthermore, the neutrality hypothesis was evident in the case of Angola and Qatar, while Ecuador was the only country with feedback hypothesis.

In the study on Malaysia by Solarin and Shahbaz (2015), the feedback hypothesis was confirmed. Studies on the theme for Iran are

[1] For brevity, interested readers can see the literature studies of Payne (2010) and Ozturk (2010) for more insight on the testable causality hypotheses.

Table 1
Summary of literature on Natural gas-economic growth nexus.

Authors and Year	Time	Region	Methodology	Empirical Finding
Akadiri and Akadiri (2018)	1980–2013	Iran	ARDL, TY	Y x NG
Hafeznia et al. (2017)	N/A	Iran	Descriptive statistics, Graphs	NG ↔ Y
Esen and Oral (2016)	N/A	Iran, Russia, Qatar, Turkmenistan	Descriptive statistics, Graphs	NG ↔ Y
Furuoka (2016)	1980–2012	China	ARDL,GC,TY	NG → Y
Solarin and Ozturk (2016)	1980–2012	OPEC member countries	Panel GC	NG ↔ Y
Balitskiy et al. (2016)	1997–2011	EU-26	Panel cointegration	NG↔ Y
Destek (2016)	1991–2013	OECD countries	FMOLS, DOLS Panel VECM	NG↔ Y
Shahiduzzaman and Alam (2014)	1970–2009	Australia	ARDL	NG ↔ Y
Bildirici and Bakirtas (2014)	1980–2011	Brazil, Russia and Turkey	ARDL, JML,GC	NG ↔ Y
Solarin and Shahbaz et al. (2015)	1971–2012	Malaysia	BH,ARDL, VECM,	NG ↔ Y
Rafindadi and Ozturk (2015)	1971–2012	Malaysia	ARDL,BH,GC	NG ↔ Y
Ozturk and Al-Mulali (2015)	1980–2012	Gulf Cooperation Council (GCC) Countries	Pedroni cointegration test	NG ↔ Y
Dogan (2015)	1995–2012	Turkey	VECM, GC	NG ↔ Y
Farhani et al. (2014)	1980–2010	Tunisia	ARDL, TY	NG↔ Y
Saboori and Sulaiman (2013)	1980–2013	Malaysia	ARDL, JML, GC	NG ↔ Y
Shahbaz et al. (2013b)	1972–2010	Pakistan	ARDL,JML,GC	NG → Y
Das et al. (2013)	1980–2010	Bangladesh	JML,GC	Y → NG
Kum et al. (2012)	1991–2008	Korea	GC	NG ↔ Y
Lotfalipour et al. (2010)	1967–2007	Iran	TY	NG → Y
Apergis and Payne (2010)	1992–2005	67 Countries	Pedroni cointegration	NG ↔ Y
Ighodaro (2010)	1970–2005	Nigeria	VECM, JJ	NG → Y
Isik (2010)	1977–2008	Turkey	ARDL	NG ↔ Y
Amadeh et al. (2009)	1973–2003	Iran	ARDL, VECM	NG ← Y
Reynolds and Kolodziej (2008)	1928-1987,1988–1991,1992–2003	Soviet Union	GC	NG → Y
Hu and Liu (2008)	1973–2003	Taiwan	VECM	NG ← Y
Sari at al. (2008)	2001–2005	US	ARDL, VECM	NG ← Y
Zamani (2007)	1967–2003	Iran	JML, VECM	NG ↔ Y
Lee and Chang (2005)	1954–2003	Taiwan	JML, WE	NG → Y
Siddiqui (2004)	1970–2003	Pakistan	ARDL, HGC(Hsiao's Granger Causality Test)	NG x Y
Fatai et al. (2004)	1960–1999	New Zealand and Australia	ARDL, JML, TY	Y x NG
Aqeel and Butt (2001)	1955–1996	Pakistan	GC	Y x NG
Yang (2000)	1954–1997	Taiwan	GC	NG → Y
Yu and Choi (1985)	1947–1974	US, UK	GC	NG ← Y

Note: NG- Natural gas consumption, Y- economic growth. Where NG → Y means one-way causality from NG consumption to economic growth and Y → NG is from economic growth to NG consumption. Y ↔ NG depicts a feedback Granger causality and Y x NG denotes neutrality hypothesis where there is no causal interaction between NG and Y. Also in Table 1 above N. A-not applied. The following abbreviation tests are rendered as Autoregressive Distributed Lag Model to Cointegration (ARDL), Granger Causality (GC). Also the (JML) mean Johansen's Maximum Likelihood technique, Johansen Juselius cointegration(JJ), Vector Error Correction Model(VECM) Bayer and Hanck cointegration test(BH) and Toda and Yamamoto causality tests (TY) respectively.

limited. However, Zamani (2007), using the vector error correction model (VECM), examined disaggregated energy consumption estimates from 1967 to 2003 and found a long run bidirectional causality relationship stemming from economic growth to NG consumption. More recently, Esen and Oral (2016) and Hafeznia et al. (2017) affirmed the significant contribution of NG to economic growth in the various investigated countries.

Kum et al. (2012) examined relationship between NG consumption and economic growth in the G-7 countries (US, UK, Japan, Italy, Germany, France and Canada) for the period 1970–2008. With control for capital in the model, test results showed causality flowing from NG consumption towards economic growth for Italy, whereas in the case of UK no causality is established from NG consumption to economic growth. From the results, it also revealed US, Germany and France were observed to have bidirectional causality whereas for Canada and Japan no causal relationship was established. Lotfalipour et al. (2010) investigated into causal relationships between economic growth, carbon emissions and fossil fuels consumption for Iran during 1967–2007 period. Proxying with NG consumption, results revealed unidirectional Granger causality flowing from NG consumption to GDP. Saboori and Sulaiman (2013) investigated into the relationship between NG consumption and economic growth in Malaysia from 1980 to 2009. In the short run, evidence is observed from the result showing unidirectional causality flowing from NG consumption to economic growth. In the case of long run from the same result, bidirectional causality is evident between NG consumption and carbon emissions, economic growth and NG consumption.

The problem of omission of important variable is minimized using the trivariate approach, through addition of extra variable is of little effect to resolve this problem. This has necessitated recent studies to adopt the use of multivariate framework to resolve this issue. Shahbaz et al. (2013c) examined the relationship in Pakistan covering the period from 1972 to 2010. Export, capital and labor were added in the multivariate model. Variance decomposition analysis was carried to establish causal relationship flowing from the NG consumption to economic growth. Apergis and Payne (2010) investigated the relationship between NG consumption and economic growth for the period of 1992–2005 using panel of 67 countries. This study included capital formation and labor force to the model. With the use of heterogenous panel cointegration, there was evidence of bidirectional causality and long run relationships between economic growth and NG consumption.

According to the studies of Farhani et al. (2014) who explored the role of NG consumption with fixed capital formation and trade over the specified period 1980–2012 on Tunisia economic growth. Result revealed bidirectional causal relationship between NG consumption and economic growth. Ighodaro (2010) examined the link between NG utilization and economic growth in Nigeria for the period 1970–2005. With the inclusion of broad money and health expenditure variables into the model, evidence from the result revealed unilateral causal relationship as well as long run link flowing from NG utilization to economic growth.

While research on energy-economic growth is quite large, there is only a limited number, which tested the income-energy nexus through the channel of oil rent and natural gas consumption with each providing an inconclusive results. The studies of Emami and Adibpour (2012) clearly outlined the pivotal role of oil rent on economic growth in Iranian economic growth. As a positive shock on oil rent translate into increased economic output. On the contrary, a negative shock from oil rent birth decline in output level. The above position of oil rent driving economic growth is also consistent with the study of Mehrara (2007) for top oil exporting countries. Also, the inclusion of low-cost capital as substitute to labor in connection with expansionary and redistributive policies results in fast wage rate (Esfahanin and Yousefi, 2017). At the same time as the country's oil boom revenue rises it causes the real exchange rate to rise, this induces the demand for domestic production of tradable to shift. This will cause total factor productivity and labor productivity to increase. Thus, it on the above premise the present study seek to fill these identified gap. Where little or less attention has been documented. The current study revisit the natural gas-led growth nexus with a new perspective by the inclusion of oil rent and non-oil GDP, capital to make more a more robust theoretical and empirical contribution.

Table-1 below renders summary of studies on the theme under consideration with diverse estimation techniques for bloc or country-specific cases.

3. Methodological construction

3.1. Data

To investigate the interaction between NG consumption and economic output in Iran, a multivariate framework which also includes real gross capital fixed formation (RGFCF) (constant 2010) as proxy for physical capital is adopted. The data for real gross domestic product (RGDP) (constant 2010) as well as Non-oil GDP that disentangle impact of oil on economic growth as also account for the model construction. Real gross capital formation and carbon dioxide emissions in Kt. Oil rent was also incorporated into the study to account for the significant role of oil revenue in the Iranian economy. The data were sourced from World Bank Development Indicators (https://data.worldbank.org/indicator), while data for NG was retrieved from the U.S Energy Information Administration database (EIA, 2018). Oil rent and Non-oil GDP were sourced from the Thomson router DataStream on a quarterly basis from 1990Q1 to 2017Q4 for the econometric analysis.[2]

The study's empirical path is as follows; (i) Unit root analysis through traditional non-stationarity tests of Augmented Dickey and Fuller, 1981 and Phillips and Perron (1988) tests and added to capture for a breakpoint in stationarity analysis is the Zivot and Andrews, 1992. The aforementioned test will be employed to explore maximum integration order of the interest variables as well as aid in avoiding I(2) variables. (ii) The estimation of cointegration among the series was achieved via the Pesaran et al. (2001) Bounds testing complemented with newly advanced combined cointegration test of Bayer and Hanck (2013). Finally, Granger causality procedure is estimated to observe the causal relationships between the variables.

3.2. Model framework

The functional relationship for our study draws empirical strength from Solarin and Shahbaz (2015) and Solarin and Ozturk (2016), given as:

$$GDP = f(NGC, GFCF, OR) \quad (1)$$

$$LnGDP_t = \alpha + \beta_1 LnNGC_t + \beta_2 LnGFCF + \beta_3 LnOR + \varepsilon_t \quad (2)$$

$$Nonoil\_GDP = f(NGC, GFCF, OR) \quad (3)$$

$$LnNonoil\_GDP_t = \alpha + \beta_1 LnNGC_t + \beta_2 LnGFCF + \beta_3 LnOR + \varepsilon_t \quad (4)$$

Logarithm transformation is carried out on equation (1) to also achieve homoscedasticity.

Here, αrepresents constant while$\beta_1\beta_2$, $\beta_3$are partial slope parameter.

The *apriori* expectation of the above fitted models aligns with theory and empirical support. The expectation for $\beta_1 > 0$. That is in confirmation of the natural gas led-growth hypothesis. As natural gas, consumption contributes to economic growth. $\beta_2 > 0$. This implies that capital accumulation play a positive role in Iran economy as supported by earlier study of Akadiri and Akadiri (2018). Finally, the expected sign for β_3 is ambiguous as it could be either positive or negative depending on the time and economic structure. Empirical studies have reported mixed outcome. As a negative sign is supported by the wartime, sanctions, political instability and corruption witnessed in the energy sector with rest of the world in Iran also contributed. As oil revenue decline and lot of trading partners found substitute energy, that is, alternative and other trading hub also had it toll on the country economy see (Mehrara, 2007; Emami and Adibpour, 2012). On the contrary, a positive sign is also visible if all earlier mentioned menace are control for, especially corruption in the energy sector that has crippled economic progress over the years in Iran (World Bank, 2017).

3.3. Stationarity test

The need for unit root and stationarity test in time series analysis is pertinent among variables. This is essential to appraise the variables order of integration. This is in quest to avoid spurious regression. The econometrics literature has well documented numerous tests, among which are the Augmented Dickey and Fuller, 1981, Phillips and Perron (1988) and Elliott et al., 1992 test. A shortcoming of the conventional unit root tests highlighted above is that they fail to account for structural break(s). These tests offer invalid and inconsistent estimates in presence of structural break(s) dates. It is however a well-known fact that most macro finance and economic datasets are plagued with structural breaks reflecting economic episodes and events. Thus, our study complements the conventional unit root tests with Zivot-Andrews unit root test. The Zivot-Andrews unit root test is reputed to account for a single structural break.

The Formula for ZA test models are given below as:

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \gamma DU_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (5)$$

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \varphi DT_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (6)$$

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \gamma DU_t + \varphi DT_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (7)$$

where the dummy variable DU_t shows the shift that occurs at each point of possible breaks at either intercept, trend or both intercept and trend. The ZA unit root test has a null hypothesis of (unit root), meaning, $H0: \theta > 0$ against an alternative (stationarity), $H1: \theta < 0$. That is, failure to reject H0 means the presence of unit roots while and rejection implies stationarity.

3.4. Cointegration test

The econometrics literature has well documented several procedures for cointegration relationship among interest series. Two series are said to have a long-run relationship (cointegrated), if there is

[2] Data interpolation technique available at E-views 10is employed to convert all annual data into quarterly frequency. Our study leverages on the study of (See Shahbaz and Lean, 2012).

somewhat linear combination among such series. Examples of the available cointegration tests are Engle and Granger, 1987, Johansen and Juselius (1990), Philips and Ouliaris (1990), Johansen (1991). Others include Gregory and Hansen (1996) and Carrion-i-Silvestre and Sansó (2006). However, all aforementioned tests have varying conclusions ranging from cointegration to non-cointegration null hypothesis. Bayer and Hanck (2013) recently advanced cointegration test provides more robust results by the amalgamation of different individual test statistics premised on the test Engle and Granger (1987), Johansen (1991), Boswijk (1995) and Banerjee et al. (1998) tests. The Fishers' formulae of the combined Bayer and Hanck (2013) test is provided below as outlined in a study by Shahbaz et al. (2016).

$$EG - JOH = -2[\ln(P_{EG}) + (P_{JOH})] \tag{8}$$

$$EG - JOH - BO - BDM = -2[\ln((P_{EG}) + (P_{JOH}) + (P_{BO}) + (P_{BDM}) \tag{9}$$

here, P_{EG}, P_{JOH}, $P_{BO} and P_{BDM}$ are the corresponding probability values of the various individual cointegration tests.

3.5. Autoregressive distributive lag (ARDL) approach

Furthermore, to reinstate the robustness of cointegration between NG consumption and economic output, gross fixed capita formation, and carbon dioxide emissions, we leverage the ARDL bounds testing technique that offers more robust and efficient estimates on the case of small sample size when compared to other conventional cointegration tests. Furthermore, the ARDL bounds test reports both short and long run dynamics of the fitted regression alongside the error correction model term (ECT) simultaneously. In addition to the above-mentioned merits, the technique is also useful in case of unknown order of integration of series. That is, the technique can be employed irrespective of whether the series are I(0) or I(I), but not 1(2). The model is estimated in the bounds test framework via the unrestricted error correction model where all variables are taken as endogenous. The UECM is estimated as:

$$\Delta Y = \mu_0 + \mu_1 t + \lambda_1 y_{t-1} + \sum_{i=1}^{N} \theta_1 v_{it-1} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \sum_{i=1}^{N} \sum_{j=1}^{P} \omega_{ij} \Delta V_{it-j} + \Psi D_t + \varepsilon_t \tag{10}$$

where V_t denotes vector; D_t accommodates for structural break in the framework as an exogenous variable. The test has a null of no cointegration with the bounds test, which is computed using F-statistics. The decision rule houses three scenarios. First, if the computed F-statistics is greater than upper bounds of the critical values reported, the null is rejected. Second, if F-statistic lies with both lower and upper bounds, the decision is inconclusive and third, scenario state that if F-statistic lies below the upper bounds, it a case of no cointegration. The hypotheses for the bounds test are specified below as:

H_0: $\varphi_1 = \varphi_2 = \ldots. = \varphi_{k+2} = 0$

H_1: $\varphi_1 \neq \varphi_2 \neq \ldots. \neq \varphi_{k+2} \neq 0$

3.6. Cointegration estimation equation

Cointegration regression is necessary after establishing long-run association among series. Several of such test abound in the literature, among such are fully modified ordinary least squares (FMOLS) advanced by Phillips and Hansen (1990), dynamic ordinary least squares (DOLS) by Stock and Watson (1993). Others include Park's (1992) Canonical Cointegration Regression (CCR). These cointegration estimation methodology offers robustness check of estimated regression as well as they offers reliable results in cases of small sample sizes they efficient.

3.6.1. FMOLS

When cointegration exists among series integrated at first order 'I (1)', (FMOLS) estimation offers optimal cointegrating regression estimates (Phillips and Hansen, 1990; Hansen, 1995; Phillips, 1995; Pedroni, 2001a, b). The method is able address issues of endogeneity and autocorrelation and still render robust estimates. Given the equation below:

$$Y_{i,t} = \alpha_i + \beta_i X_{i,t} + \varepsilon_{i,t} \quad \forall_t = 1, \ldots, T, \; i = 1, \ldots..N \tag{11}$$

Allowing for $Y_{i,t}$ and $X_{i,t}$ are cointegrated with slopes β_i, where β_i may or may not be homogeneous across *i*. Hence, the equation becomes:

$$Y_{i,t} = \alpha_i + \beta_i X_{i,t} + \sum_{k=-K_i}^{K_i} \gamma_{i,k} \Delta X_{i,t-k} + \varepsilon_{i,t} \quad \forall\, t = 1,2, \ldots, T, \quad i = 1, ..N \tag{12}$$

We reflect $\xi_{i,t} = (\hat{\varepsilon}_{i,t}, \Delta X_{i,t})$ and $\Omega_{i,t} = \lim_{T\to\infty} E\left[\frac{1}{T}(\sum_{i=1}^{T} \xi_{i,t})(\sum_{i=1}^{T} \xi_{i,t})\right]$ as the long covariance. Here $\Omega_i = \Omega_i^0 + \Gamma_i + \Gamma_i'$; The simultaneous covariance is depicted as Ω_i^0 also the weighted sum of autocovariance is Γ_i . Thus, the equation of the FMOLS is rendered as:

$$\hat{\beta}^*_{FMOLS} = \frac{1}{N} \sum_{i=1}^{N} \left[\left(\sum_{i=1}^{T} (X_{i,t} - \bar{X}_i)^2 \right)^{-1} \left(\sum_{i=1}^{T} (X_{i,t} - \bar{X}_i) Y^*_{i,t} - T_{\hat{\gamma}_i} \right) \right] \tag{13}$$

where

$$Y^*_{i,t} = Y^*_{i,t} - \bar{Y}_i - \frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}} \Delta X_{i,t} \; and \; \hat{\gamma}_i = \hat{\Gamma}_{2,1,i} + \hat{\Omega}^0_{2,1,i} - \frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}} (\hat{\Gamma}_{2,2,i} + \hat{\Omega}^0_{2,2,i}). \tag{14}$$

3.6.2. DOLS

The long-run regression estimator of fully modified dynamic least square can be substituted with the dynamic ordinary least squares, given her merit over the FMOLS (Saikkonen, 1991; Stock and Watson, 1993). The DOLS technique is built to be asymptotically efficient estimator as well as eliminate feedback in the cointegrating system. Econometrically, the approach estimation process contains the cointegrating regression which possess both lags and leads, considering the orthogonality in the cointegrating equation error term:

$$Y_t = \alpha_i + \beta X'_t + D'_{1t} D' \gamma_1 \sum_{j=-q}^{r} \Delta X'_{t+j} \rho + v_{1,t} \tag{15}$$

The differenced regressors with lag and lead of q and r respectively, absorbs all the long-run correlation between (ν1t and ν2t) while the least-square estimates of θ = (β′, γ′)' houses asymptotic distribution similar to canonical cointegration regression and fully modified ordinary least squares.

3.6.3. CCR

The Canonical Cointegration Regression (CCR) is unique by circumventing bias of second-order a short coming of the ordinary least squares (OLS) estimator by transformation of the variables. The covariance matrix form of the long-run estimator is rendered as:

$$\Omega = \lim_{n\to\infty} \mathrm{E} \sum_{t=1}^{n} (u_t) \sum_{t=1}^{n} (u_t)' = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{bmatrix} \tag{16}$$

where Ω can be represented as follows:

$$\Omega = \sum + \Gamma + \Gamma' \tag{17}$$

and

$$\sum = lim_{n\to\infty} \; \mathrm{E} \sum_{t=1}^{n} (u_t u'_t) \tag{18}$$

$$\Gamma = lim_{n\to\frac{1}{n}}\ \mathrm{E}\sum_{k=1}^{n-1}\ \sum_{t=k+1}^{n}\ \mathrm{E}(u_t u'_{t-k}) \tag{19}$$

$$\cap\ = \sum + \Gamma = (\cap_1, \cap_2) = \begin{bmatrix} \cap_{11} & \cap_{12} \\ \cap_{21} & \cap_{22} \end{bmatrix} \tag{20}$$

the transformed series is obtained as:

$$Y_{1t}^{*} = Y_{2t} - \sum^{-1} (\cap_2)'\ \ u_t \tag{21}$$

$$Y_{2t}^{*} = Y_{2t} - \sum^{-1} (\cap_2)' u_t \tag{22}$$

$$Y_{1t}^{*} = Y_{1t} - \left(\sum^{-1} \left(\cap_2 \beta + \left(0,\ \Omega_{12},\ \Omega_{22}^{-1} \right) \right)' \right) u_t \tag{23}$$

where CCR acquires the following form:

$$Y_{1t}^{*} = \beta' + Y_{2t}^{*} + u_{1t}^{*} \tag{24}$$

$$Y_{1t}^{*} = u_{1t} - \ \Omega_{12},\ \Omega_{22}^{-1} u_{2t} \tag{25}$$

Equation-24 the OLS estimators share the same fashion as the ML estimation. The long-run correlation of $y1t$ and $y2t$ caused asymptotically endogeneity were circumvented for by variables transformation. The asymptotic bias issue because of cross-correlation between ($u_{1\mathrm{t}}$ and $u_{2\mathrm{t}}$), were addressed in Equation-25 with the transformation of the variables.

3.7. Causality approach

The traditional regression does not imply causal interaction. Thus, there is need for causality test to probe directional causality between variables. This is necessary, given the inherent insight that can be gleaned from such estimations by policy makers and stakeholders in general. Our study employs the Granger causality approach as the primary means of detecting the predictability power that exists among the variables. When we say variable X Granger causes Y, it implies that variable X and its past realizations are good predictors of variable Y. A general model specification for the bivariate (X, Y) Granger causality test is expressed thus:

$$X_t = \gamma_0 + \gamma_1 X_{t-1} + \gamma_2 Y_{t-1} + \varepsilon_t \tag{26}$$

$$Y_t = \gamma_0 + \gamma_1 Y_{t-1} + \gamma_2 X_{t-1} + \varepsilon_t \tag{27}$$

In equation-26, the null hypothesis that X doesn't Granger cause Y is tested against the alternate hypothesis that X Granger causes Y. The hypotheses are similarly stated for equation-27. It is also worthy of note that the causal relationships can take one of the following forms; unidirectional (meaning from X to Y or vice versa), bidirectional (implying feedback relationship from both ends) and neutrality (implying no casual interaction between the variables).

3.7.1. Toda-Yamamoto Granger causality methodology

The fact that conventional regression does not connotes causality interpretation. This necessitates the need to estimate causality test. The current study relies on the modified Wald stat (MWALD) Toda-Yamamoto (1995) causality test to detect the flow of causality for the selected variables under consideration. The Toda-Yamamoto (TY, here after) is preferred to the traditional Granger causality because The TY possesses some distinct traits relative to conventional Granger causality test. The TY can be conducted regardless of cointegration relationship among variables. Also, there is no precondition of stationarity properties of variables to be either integrated of order 1 or stationary at levels. However, the variable(s) should not integrated of order 2. The TY methodology is conducted on a VAR settings, with a known VAR ($k\ +\ dmax$). Where $dmax$ denotes the maximum order of integration of the variables and K represents the optimum lag order as suggested by appropriate lag selection criterion. The present study employs a multivariate VAR ($k\ +\ dmax$) model which encompasses economic growth (GDP), oil rent, Non-oil GDP and Natural gas consumption. The model specification is rendered below as:

$$\begin{aligned} \ln GDP = {} & \phi_0 + \textstyle\sum_{k=1}^{n} \phi_{1k} \ln GDP_{t-k} + \sum_{r=m+1}^{d_{\max}} \phi_{2r} \ln GDP_{t-r} + \\ & \textstyle\sum_{k=1}^{n} \delta_{1k} \ln GFCF_{t-k} + \sum_{r=m+1}^{d_{\max}} \delta_{2r} \ln GFCF_{t-r} + \\ & \textstyle\sum_{k=1}^{n} \beta_{1k} \ln NGC_{t-k} + \sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln NGC_{t-r} + \sum_{k=1}^{n} \xi_{1k} \ln OR_{t-k} + \\ & \textstyle\sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln OR_{t-r} + \varepsilon_{1t} \end{aligned} \tag{28}$$

$$\begin{aligned} \ln NGC = {} & \beta_0 + \textstyle\sum_{k=1}^{n} \beta_{1k} \ln NGC_{t-k} + \sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln NGC_{2,t-r} + \\ & \textstyle\sum_{k=1}^{n} \phi_{1k} \ln GDP_{t-k} + \sum_{r=m+1}^{d_{\max}} \phi_{2r} \ln GDP_{t-r} + \sum_{k=1}^{n} \delta_{1k} \ln GFCF_{t-k} + \\ & \textstyle\sum_{r=m+1}^{d_{\max}} \delta_{2r} \ln GFCF_{t-r} + \sum_{k=1}^{n} \xi_{1k} \ln OR_{t-k} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln OR_{t-r} + \varepsilon_{2t} \end{aligned} \tag{29}$$

$$\begin{aligned} \ln GFCF = {} & \delta_0 + \textstyle\sum_{k=1}^{n} \delta_{1k} \ln GFCF_{t-k} + \sum_{r=m+1}^{d_{\max}} \delta_{2r} \ln GFCF_{t-r} + \\ & \textstyle\sum_{k=1}^{n} \phi_{1k} \ln GDP_{t-k} + \sum_{r=m+1}^{d_{\max}} \phi_{2r} \ln GDP_{t-r} + \sum_{k=1}^{n} \beta_{1k} \ln NGC_{t-k} + \\ & \textstyle\sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln NGC_{t-r} + \sum_{k=1}^{n} \xi_{1k} \ln OR_{t-k} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln OR_{t-r} + \varepsilon_{3t} \end{aligned} \tag{30}$$

$$\begin{aligned} \ln OR = {} & \xi_0 + \textstyle\sum_{k=1}^{n} \xi_{1k} \ln OR_{t-k} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln OR_{t-r} + \\ & \textstyle\sum_{k=1}^{n} \delta_{1k} \ln GFCF_{t-k} + \sum_{r=m+1}^{d_{\max}} \delta_{2r} \ln GFCF_{t-r} + \\ & \textstyle\sum_{k=1}^{n} \phi_{1k} \ln GDP_{t-k} + \sum_{r=m+1}^{d_{\max}} \phi_{2r} \ln GDP_{t-r} + \sum_{k=1}^{n} \beta_{1k} \ln NGC_{t-k} + \\ & \textstyle\sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln NGC_{t-r} + \varepsilon_{4t} \end{aligned} \tag{31}$$

where GDP, NGC, OR and GFCF are all expressed in section 3.1. Also, ε_{1t}, ε_{2t} and ε_{3t} represent stochastic terms for fitted models. Where k denotes the optimal lag order. By using the standard Chi-square statistics, Wald tests are employed to the first n coefficient matrices.

4. Empirical findings and discussions

In time series estimations, it is essential to have a visual plot of the variables in order to have a glimpse of how the dataset fares. Fig. 4 below shows the variables under review. From Fig. 1, it is conspicuous that there exists noticeable structural break(s). Thus, our study modelled for such break(s) in the estimation section. Table 2 reports the basic summary (descriptive) statistics and correlation matrix analysis in the panel. Table 2 shows that all series investigated are normally distributed as reported by the Jarque-Bera probability which is desirable. Also observed is obvious significant disparity between the minimum and maximum over the period investigated, which is worth further investigation. The correlation matrix is also reported at the bottom of Table 2. The correlation results show a positive association between NG intake and economic output (GDP) for the study area, which is desirable and expected for Iran, being a net exporter of NG. Also revealed is significant positive synergy between RGFCF and economic growth, thus suggesting the key role of real gross capital formation in the Iranian economy. Similar positive association is seen between oil revenue and economic growth which give credence to Iran as oil exporting country. This is instructive and informative to policy economists (see Fig. 5).

Tables 3 and 4 renders the unit root test analysis. The need for the tests enhances accuracy of estimates and by extension avoid pitfall of misleading policy implication(s). Our study adopts the traditional unit root tests of ADF and PP. However, given the established criticism on the tests with size and power problem, we complement with Zivot-Andrews (ZA) unit root test that circumvents for these pitfalls mentioned. All unit root tests are in harmony. That is, all the variables (that is, real GDP, NG consumption, real gross fixed capital formation, oil revenue and non-oil GDP) are integrated of order one I(1). Table 4 reports Zivot-Andrews unit root test that presents breaks. The estimated

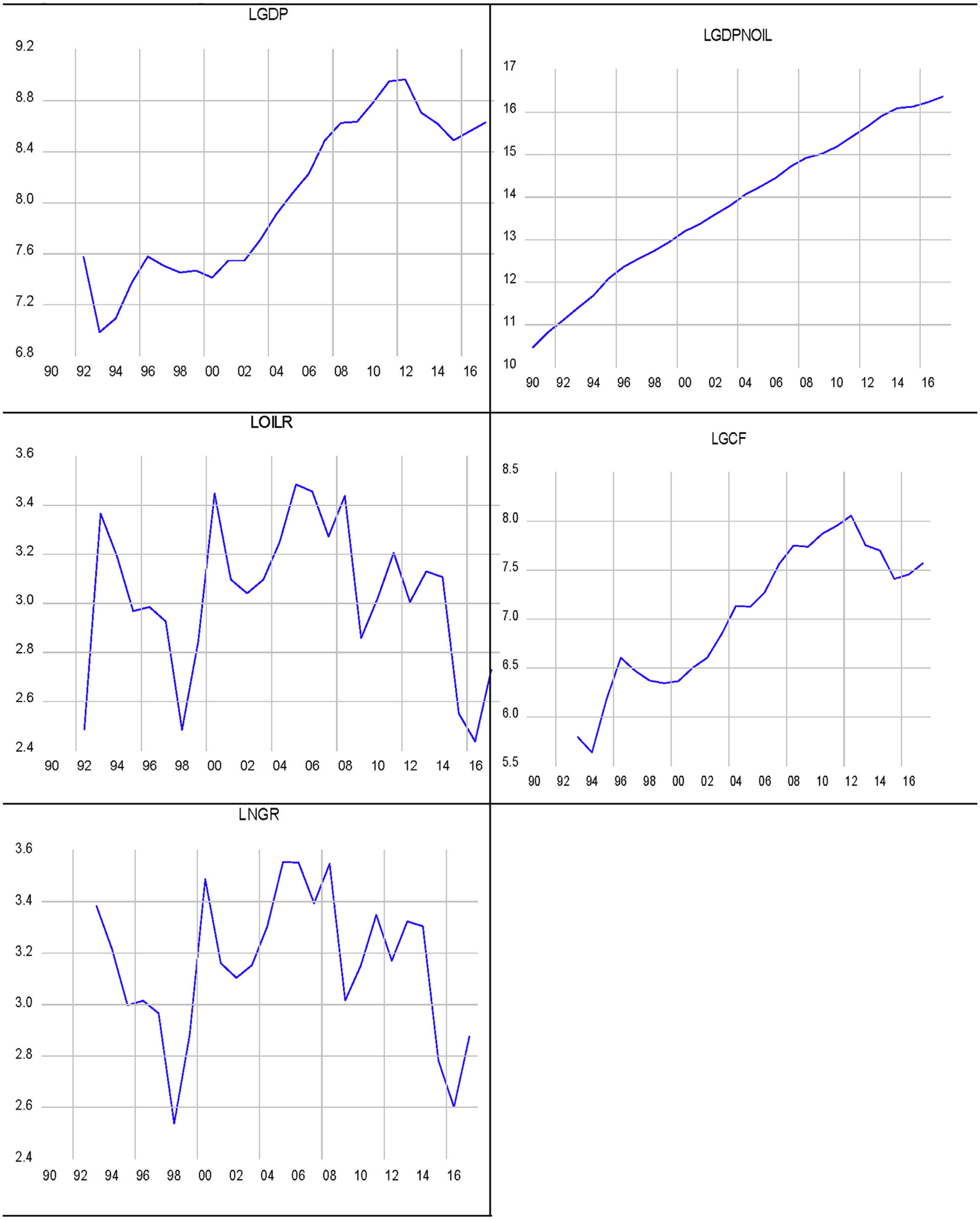

Fig. 4. Visual plot of variables under consideration
Source: Wold Bank (2018).

break dates resonate with significant economic and political episodes of western sanctions and war periods in Iran. For example, the pre crises of global financial crises of 2006Q2 was captured. Also, the impact of sanctions imposed on Iran by most western nations, especially the US in the late 1980s is visible in natural gas variable and economic growth variable.

Table 5 above reports the lag selection criterion. This is done to choose the most parsimonious and appropriate model. Our study adopts the Schwarz information criterion (SIC) for all subsequent analyses. The SIC is chosen over other available information criteria because of the large sample size and structure of our study. Table 6 reports the cointegration relationship for all estimated models and affirms

Table 2
Descriptive and correlation coefficients matrix estimate.
Source: Authors' computation.

	LGCF	LGDP	LNNGC	LOILR	LGDPNOIL
Mean	7.0438	8.0535	3.1531	3.0562	14.1660
Median	7.1354	8.0758	3.1606	3.0973	14.2500
Maximum	8.0583	8.9661	3.5541	3.4856	16.3652
Minimum	5.6355	6.9852	2.5360	2.4372	11.4015
Std. Dev.	0.7116	0.6261	0.2806	0.2936	1.5240
Skewness	−0.3243	−0.0815	−0.4585	−0.4963	−0.1775
Kurtosis	1.9009	1.5427	2.5794	2.6479	1.8396
Jarque-Bera	1.6966	2.2398	1.0601	1.1553	1.5339
Probability	0.4281	0.3263	0.5886	0.5612	0.4644
LGCF	1.0000				
LGDP	0.9864	1.0000			
LNGC	0.1413	0.0944	1.0000		
LOILR	0.0473	0.1006	0.9766	1.0000	
LGDPNOIL	0.9192	0.9331	0.0170	0.2173	1.0000

Table 3
Unit root test results (without break).
Source: Authors' computation. Note:*. **, denotes 1% and 5% significance rejection level respectively. Mackinnon (1996) one sided P-value is reported. Models with intercept and trend were reported for all test statistics. ( ) denotes optimal lag length.

Panel A: Level		
Variables	ADF	PP
Ln GDP	−2.2805(1)	−1.4473(1)
LnNGC	−2.2636(1)	−2.6048(1)
LnGFCF	−2.2804(1)	−1.4473(1)
LnOILR	−2.0877(1)	−1.3349(1)
LnGDPNOIL	−1.5112(1)	−1.9817(1)
Panel B: First Difference		
Variables	ADF	PP
Ln GDP	−4.8588(1)*	−5.0679(1)*
LnNGC	−3.2091(1)*	−2.6048(1)*
LnGFCF	−4.8587(1)*	−4.8723(1)*
LnOILR	−5.2129(1)*	−4.7304(1)*
LnGDPNOIL	−4.5248(1)*	−4.3972(1)*

Table 4
Zivot and Andrews unit root test results (with a single structural break date).
Source: Authors' computation. Note:*. **, denotes 1% and 5% significance level of rejection respectively. Δ Denotes first difference and numbers in ( ) represents lag length.

Variables	level		Δ	
	ZA test-stat.	Break Period	ZA test-stat.	Break Period
LnGDP	−4.7194(1)	2006Q2	−5.7194(1)* *	2006Q2
LnNGC	−3.5610(1)	2004Q2	−5.1224(1)*	2004Q2
LnGFCF	−4.1319(1)	2000Q2	−5.1319(1)*	2006Q2
LnOILR	−4.9720(1)	2004Q3	−5.7726(1)**	1999Q3
LnGDPNOIL	−2.8101(1)	2012Q3	−5.8215(1) **	2012Q3

cointegration (long-run equilibrium) relationship. That is, there is a convergence between the real GDP, real fixed gross capita formation, oil revenue and non-oil GDP. This is established by the rejection of null hypothesis of no cointegration. Table 6 used the real GDP and Non-oil GDP variables as dependent variable for the period under consideration. As a form of robustness check, we further carry out cointegration by ARDL bounds testing. The bounds test results presented in Table 7 corroborates the Bayer and Hanck results to confirm equilibrium relationship among investigated series while controlling for structural break dates in the estimation.

Having confirmed cointegration relationship among investigated variables, it becomes pertinent to investigate the long-run equilibrium coefficients. To achieve this, DOLS, FMOLS and CCR regressions are estimated to illustrate the magnitude of cointegration. The DOLS possesses some unique traits that allow for estimation irrespective of the integration order of the variables. However, the explained variable is required to be integrated of order one. Also, the technique helps to ameliorate the issue of serial correlation and other internalities (Esteve and Requena, 2006).

The empirical results reflect a negative connection between income and oil rents; while natural gas rents and gross fixed formation present a positive connection with income in Iran between 1990 and 2017. The negative connection between oil rents and economic growth would be motivated by the existence of irregular behaviours (Arezki and Brückner, 2011) in Iranian economy system, as consequence of corruption, development of political rights or civil liberties, which would reduce income levels in Iran (Ross, 1999; Arezki and Brückner, 2011). Thus, we consider that policymakers should be aware of the impact of oil rents over redistribution and corruption, in order to adopt measures to attract the promotion of renewable technologies.

On the other hand, natural gas rents have contributed positively to enhance ascending economic growth in Iran (Mastorakis and Khoshnevis, 2014; BP, 2018). Pirlogea and Cicea (2012) found that natural gas consumption causes economic growth in Spain. The position of natural gas induced economic growth is also consistent to the study of Shahbaz et al. (2013c) found that natural gas consumption contributes economic growth in case of Pakistan. For the Iranian case, the country has been reflected as the second most massive natural gas field and the third producer of natural gas in the world as outlined by (EIA, 2018; BP, 2018). Iran was ranked the third largest natural gas producer in the world with more than 223 billion cubic meters of natural gas,

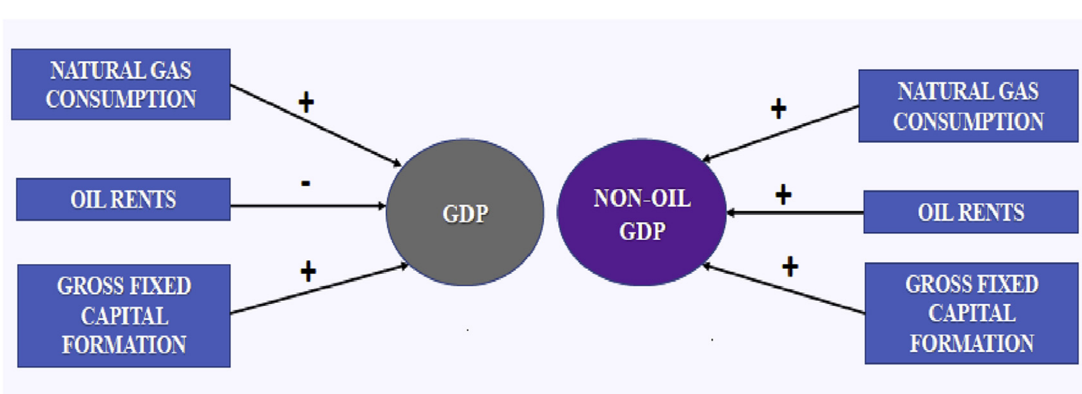

Fig. 5. Estimation Scheme
Note: Oil rents are not significant in both models.

Table 5
Lag criteria selection.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	107.1262	NA	1.62E-06	−1.9832	−1.88149	−1.941992
1	760.7183	1244.339	7.65E-12	−14.2446	−13.7361	−14.03856
2	841.2461	147.1181	2.22E-12	−15.4855	−14.57014*	−15.11466
3	849.749	14.88006	2.57E-12	−15.3413	−14.0191	−14.80567
4	855.0098	8.801689	3.18E-12	−15.1348	−13.4058	−14.43432
5	911.5698	90.27845	1.47E-12	−15.9148	−13.779	−15.04951
6	961.5902	75.99257*	7.78e-13*	−16.56904*	−14.0264	−15.53893*
7	968.0209	9.275018	9.56E-13	−16.385	−13.4355	−15.19008
8	972.8521	6.59645	1.22E-12	−16.1702	−12.8139	−14.81048

Note: where LR represent sequential modified LR statistic, FPE means Final prediction error. Also Akaike information criterion (AIC), Schwarz information criterion (SIC) and finally Hannan Quinn information (HQ).

Table 6
Bayer and Hanck combined cointegration test results.
Source: Authors' computation. Note:*,**represents 1%, 5% significance rejection levels respectively Critical values for EG-JOH at 1% and 5% are 16.259 and 10.637 respectively, while for EG-JOH-BO-BDM are 31.169 and 20.486 respectively.

Models	EG-JOH	EG-JOH-BO-BDM	Structural break	cointegration remark
GDP = f(NGC,GCF,OR)	55.3399*	165.8640*	2006Q2	Yes
GDPNONOIL = f(NGC,GCF,OR)	56.8783*	115.8017*	2004Q2	Yes

Table 7
The ARDL test results.
Source: Authors' computation. Note:*,**represents 1%, 5% significance rejection levels respectively.

Cointegration by bounds testing		Diagnostic test				
Models	Optimal length	Break year	F-statistics	χ^2white	χ^2ARCH	χ^2RESET
GDP = f(NGC,GCF,OR)	1,1,1,1	2006Q2	10.4592*	0.0876	0.3917	0.4010
GDP Non-oil = f(NGC,GCF,OR)	1,1,1,1	2004Q2	4.4768**	0.2805	0.1024	0.9167
Critical values						

	lower bounds 1(0)	Upper bounds 1(1)
1%	3.65	4.66
5%	2.79	3.67
10%	2.37	3.20

Table 8
FMOLS, DOLS and CCR estimation results.
Source: Authors' computation. Note: *, **,*** represents 0.01, 0.05 and 0.10 rejection significant levels respectively. [ ] are t-statistics.

Depend variable:	LGDP			LNON-OILGDP		
Variable	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
LNGC	1.327634***	2.039091*	1.189030***	15.22846*	11.80752*	11.53284*
	[1.682315]	[4.834001]	[1.577982]	[7.998999]	[6.855349]	[6.690059]
LOILR	−0.153383	−0.034686	−0.166754	0.375406	0.088231	0.093588
	[-0.908267]	[-0.345241]	[-1.046020]	[0.921483]	[0.215077]	[0.253148]
LGCF	1.717058*	1.844281*	1.676716*	6.302501*	5.601793*	5.502739*
	[11.34080]	[24.50437]	[12.38714]	[17.25528]	[18.22823]	[17.60868]
C	−46.72872*	−56.74880*	−44.41514*	−283.7136*	−234.1770*	−229.1904*
	[-4.690380]	[-10.60986]	[-4.813933]	[-11.80470]	[-10.72255]	[-10.91274]
R-squared	0.817568	0.889370	0.817089	0.870523	0.933854	0.898817
Adjusted R-squared	0.812453	0.875541	0.811961	0.866893	0.925586	0.895980
S.E. of regression	0.273145	0.223339	0.273504	0.635347	0.465999	0.561653
Long-run variance	0.225057	0.043931	0.225057	1.309762	0.732442	1.225689
Mean dependent var	7.983437	7.978626	7.983437	13.83643	13.84409	13.83643
S.D. dependent var	0.630724	0.633071	0.630724	1.741447	1.708275	1.741447
Sum squared resid	7.983096	4.788523	8.004068	43.19231	20.84686	33.75357

enjoying a 6.1-percent share in the global gas market (BP, 2018). The replacement of oil products with natural gas consumption was an essential policy of government in energy sector during the fourth development plan (2005–2009). Nowadays, more than 40% of total energy consumption in Iran is provided by natural gas, reflecting the relevance of this energy factor in the process of economic growth and development plans (BP, 2018). We can as main reasons in the increasing rate of natural gas consumption is due to the low price of domestic supply of

Table 9
Pairwise Granger causality tests.

Null Hypothesis:	Causality	F-Statistic	Prob.
LNNGC ≠ > LNGDP	GDP↔NGC	2.64256	(0.0379)
LNGDP ≠ > LNNGC		3.41028	(0.0137)
LNOR ≠ > LNGDP	GDP↔OIL RENTS	139.299	(2.E−11)
LNGDP ≠ > LNOR		2.30640	(0.0622)
LNGFCF ≠ > LNGDP	GDP →GFCF	1.13801	(0.4245)
LNGDP ≠ > LNGFCF		3.32265	(0.0153)
LNGDP_NON_OIL ≠ > LNGDP	NON-OIL GDP→GDP	8.93305	(0.0001)
LNGDP_CURRENT ≠ > LNGDP_NON_OIL		1.74898	(0.1514)
LNOR ≠ > LNNGC	OIL RENTS →NGC	3.25689	(0.0166)
LNNGC ≠ > LNOR		1.84008	(0.1302)
LNGFCF ≠ > LNNGC	GFCF→NGC	15.7445	(6.E−06)
LNNGC ≠ > LNGFCF		0.87441	(0.6389)
LNGDP_NON_OIL ≠ > LNNGC	NON-OIL GDP ≠NGC	1.00636	(0.5245)
LNNGC ≠ > LNGDP_NON_OIL		0.57483	(0.8973)
LNGFCF ≠ > LNOR	GFCF→OIL RENTS	2.34405	(0.0587)
LNOR ≠ > LNGFCF		1.06388	(0.4789)
LNGDP_NON_OIL ≠ > LNOR	OIL RENTS→NON-OIL GDP	1.24691	(0.3540)
LNOR ≠ > LNGDP_NON_OIL		2.57140	(0.0420)
LNGDP_NON_OIL ≠ > LNGFCF	GFCF→NON OIL-GDP	0.73563	(0.7658)
LNGFCF ≠ > LNGDP_NON_OIL		4.67394	(0.0034)

Note ≠ > means does not Granger cause.

natural gas that leads to economic justification of the use of wasting energy technologies, non-optimal allocation, in appropriate and abundant use of natural gas. So, unlike the pattern of natural gas consumption in industrialized countries, the highest share of its consumption in Iran is allocated to the household and commercial sectors (Mastorakis and Khoshnevis, 2014).

During last years, sanctions has reduced gross capital formation in Iran, especially in construction investment and public investment (World Bank, 2017). From our piece of empirical results this variable presents a positive connection with income level, suggesting the necessity of an advance in non-oil sectors, related with more sustainable growth. Hence, in medium-term the growth rates are expected to revert to an average of 4% in Iran (World Bank, 2017), reflecting the positive effect that measures connected with sustainable growth would exert over this situation. So, our study suggests that the non-oil sector and private investments play a significant role, even oil sector lessens the enlargement of Iranian economy.

Our study further reveals that a 1% increase in NG consumption translates into a corresponding increase in economic growth by a magnitude of 1.3276%, 2.039091% and 1.1890% for FMOLS, DOLS and CCR respectively. Likely a 1% increase in NG consumption will amount into a corresponding increase in non-oil GDP by the following magnitude 15.2284%, 11.8075% and 11.5328% for FMOLS, DOLS and CCR respectively.

Interestingly, our study observes positive synergy between real gross capital formation, economic growth and non-oil GDP. This is a call for Iran to strengthen her institutions in order to enhance capital accumulation both in the short and long-run and consequently grow her economy.

The fitted model residual diagnostic tests results indicate that the model is adequate for policy construction given it free from autocorrelation, model miss specification and heteroscedasticity.

Fig. 2 further buttresses the argument that the fitted model with real GDP as dependent variable in Table 8 is stable, given the CUSUM and CUSUMSQ stability lines lie within the 5% threshold interval, an indication that the model is stable.

Table 9 (Fig. 7) reports causality flow of the variables under review (see Fig. 6). As shown, there exists a unidirectional causality running from gross capital formation to NG consumption. This implies that capita formation is essential for increase NG consumption. Similar trend of unidirectional causality flow is seen running from real GDP to gross capital formation. Our study gives support to a bidirectional causality between NG consumption and economic growth (Bildirici and Bakirtas, 2014; Solarin and Shahbaz, 2015; Ozturk and Al-Mulali, 2015; Dogan, 2015; Farhani et al., 2014; Saboori and Sulaiman, 2013; Balitskiy et al., 2016; Destek, 2016; Solarin and Ozturk, 2016; Esen and Oral, 2016; Hafeznia et al., 2017, among others-see Table 1). This study joins the group of studies that support the NG-economic growth hypothesis (Lee and Chang, 2005; Reynolds and Kolodziej, 2008; Shahbaz et al., 2013c). However, NG driven economic growth is not a panacea for Iran's sustainable economic growth, given the dwindling price and energy market dynamics globally. This implies that there is need for diversification of the energy portfolio in Iran to more environmental friendly sources like renewable energy sources is encouraged by this study (see Fig. 8) (see Table 10).

The empirical results also support bidirectional causality between oil rents and economic growth in Iran, in line with Najjarzadeh and Mohsen (2004) and Shahbazi (2013), who showed similar results for

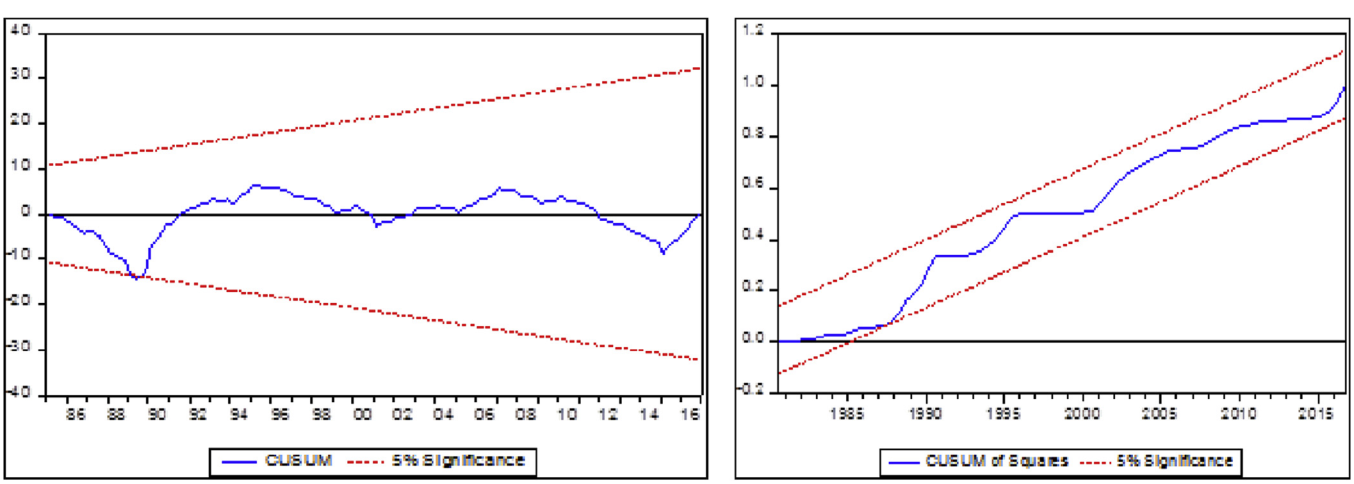

Fig. 6. CUSUM and CUSUM Sq.

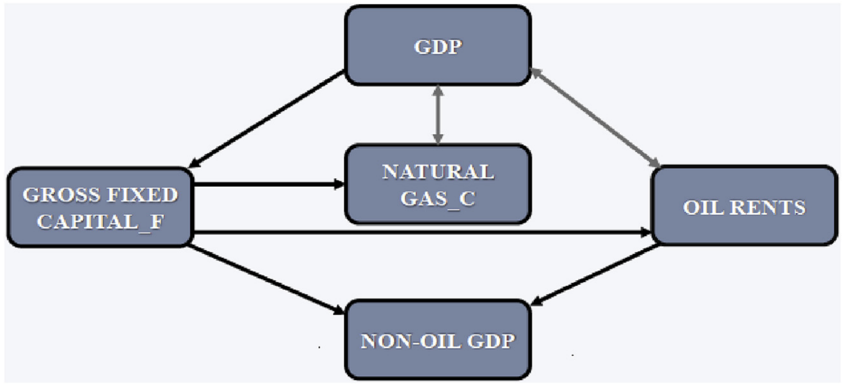

Fig. 7. Granger causality Scheme.

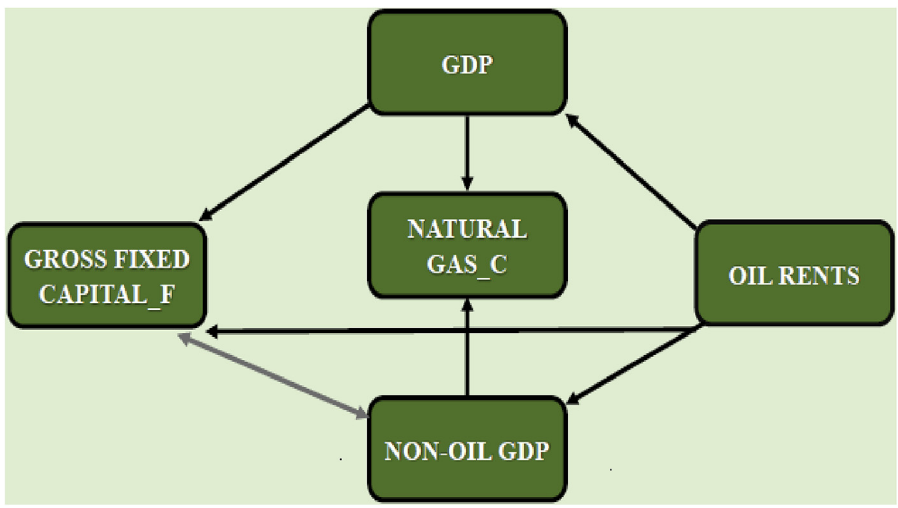

Fig. 8. VAR Granger causality Scheme.

Table 10
VAR Granger causality/block exogeneity Wald tests.

	LNOR	LNGDP	LNGDP_NON_OIL	LNGFCF	LNNGC
LNOR	–	3.333597	4.209967	2.835539	7.708327
	–	(0.8525)	(0.7553)	(0.8998)	(0.3590)
LNGDP_CURRENT	22.96774*	–	1.223886	10.63416	5.416463
	(0.0017)	–	(0.9904)	(0.1554)	(0.6093)
LNGDP_NON_OIL	13.96621**	17.07111*	–	20.05350*	5.962063
	(0.0518)	(0.0169)	–	(0.0055)	(0.5442)
LNGFCF	5.270676	13.56803**	12.28014***	–	11.16886
	(0.6270)	(0.0594)	(0.0917)	–	(0.1314)
LNNGC	15.36548*	14.30384**	7.05745***9	7.743422	–
	(0.0316)	(0.0460)	(0.0917)	(0.3558)	–
All	53.96707	37.03443	37.33722	59.21306	32.82844
	(0.0023)	(0.1181)	0.1116	(0.0005)	(0.2421)

Iran. The causality results validate the feedback hypothesis between energy and economic growth in Iran.

Finally, we apply Toda-Yamamoto causality test to reinforce empirical results.

5. Concluding remark/policy implications

This country-specific study seeks to investigate the interaction between natural gas consumption-economic growth nexus for the case of Iran by the inclusion of real gross fixed capital formation and oil rents as additional variables in a multivariate framework in order to avoid omitted variable bias which previous studies failed to address. To do this, quarterly data from 1990Q1 to 2017Q4 sourced from World Bank Development Indicators (https://data.worldbank.org/indicator) and the U.S Energy Information Administration database (EIA, 2018) was used for the econometric analyses. This study accounts for structural break in all estimations. For stationarity testing, beyond the conventional Augmented Dickey Fuller (ADF) and Phillips Perron tests, the Zivot Andrews unit root test that accounts for single structural break was also employed. For the cointegration analysis, with the noted break year properly accounted for in the estimation combined cointegration advanced by Bayer and Hanck (2013) is employed. The Bayer and Hanck (2013) test result was further confirmed via the Pesaran ARDL bounds testing to cointegration approach as a form of robustness test.

For causal interaction, the Granger pairwise causality and the Toda-Yamamoto Granger block exogeneity Wald test is used to reinforce causality results. Empirical findings reveal bidirectional causality seen between natural gas consumption and economic growth, confirming the feedback hypothesis for the study area. Thus, government officials in Iranian are encouraged to promote more efficient use of natural gas, in order to enhance the process of economic growth. The promotion of natural gas sources will improve the use of a safe energy utilization, with lower cost of production (Shahbaz et al., 2013a). Further empirical investigation reveals cointegration among the variables under several structural breaks. Thus, it implies that there exists a long-run bond between interests variables (cointegration) over the period considered. This finding is a pointer that in the long-run capital formation, NG consumption and oil rents are drivers of long run economic growth in Iran.

Empirical finding from the study gives credence to the NG consumption-induced economic growth hypothesis as causality interaction is observed from consumption of natural gas to economic output. Thus, it implies that embarking on aggressive NG exploitation and exploration will spur economic growth. Cleaner energy sources like solar energy, wind energy and biomass among others is crucial and encouraged in Iran. This is in agreement with the claim put forth in the recent study of Balsalobre-Lorente et al., 2018 for 5-EU countries that confirm the positive role of renewable energy rather than fossil fuel energy sources which are not as clean as natural gas and already mentioned cleaner energy sources (Saidi and Hammami, 2015; Emir and Bekun, 2018).

Further piece of empirical results shows a unidirectional contribution from gross fixed capita formation to NG consumption both in the long and short run. It is instructive that in Iran, capital plays a positive and significant role in economic output. Our empirical results validate the necessity of sustainable growth connected through attraction of foreign capital investments via financial liberalization and promotion of clean energy sources. As a way for further research direction and contribution to literature, other scholars can query the theme under review by accounting for asymmetry in the econometric modelling. There is also room to investigate a panel of net exporters of NG so as to ascertain if NG consumption drives economic growth in this set of countries.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resourpol.2019.101485

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