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Abstract

Natural gas is an important energy resource that is used to produce the national output of Pakistan. On the other hand, since natural gas is a relatively cleaner energy resource compared to oil and coal, enhancing the level of natural gas use is believed to improve the environmental quality in Pakistan which, in turn, can be expected to enable the nation to sustain its economic performances. Hence, it is pertinent to assess the effects of natural gas consumption on the nation's economic growth level. The main objective of this paper was to explore the asymmetric effects of natural gas consumption, controlling for financial development, on Pakistan's economic growth level over the 1965-2019 period. The results from the Augmented Dickey-Fuller, Phillips-Perron, and Zivot-Andrews unit root tests confirmed a mixed order of integration among the variables. Besides, the bounds test and Gregory-Hansen cointegration analysis revealed evidence of long-run associations between economic growth, natural gas consumption, and financial development. Moreover, the outcomes from the non-linear autoregressive distributed lag model showed that in the short-run positive changes in the natural gas consumption levels increase economic growth in Pakistan. On the other hand, in the long-run, positive and negative changes in natural gas consumption levels increase and decrease the economic growth level, respectively, in the long-run. On the other hand, both positive and negative changes in the financial development level are found to reduce the economic growth level in the long-run.

Furthermore, the Hacker-Hatemi-J causality analysis verified that natural gas consumption influences the economic growth level in Pakistan; thus, the energy consumption-led growth phenomenon was unearthed. In line with these key findings, several policy level suggestions are put forward for Pakistan to boost its natural gas consumption figures in order to enhance its economic growth level in the future.

Keywords: economic progress; natural gas; NARDL; financial development; Pakistan; causality

1. Introduction

Energy supply is one of the critically important factors of production in the contemporary era (Rehman et al., 2018; Magazzino et al., 2021). Although coal and oil are the major fossil fuels used globally, the environmental complications associated with the combustion of these energy resources have motivated world economies to look for relatively cleaner alternatives (Irfan et al., 2020). In this regard, mitigating fossil fuel dependency to promote greater use of non-fossil fuels utilization for producing output has been recommended in several studies (Hussain & Rehman, 2021; Rehman et al., 2019a). However, the adoption of cleaner energy resources is often inhibited due to various macroeconomic constraints experienced by the developing nation, in particular (Irfan et al., 2021; Xue et al., 2021; Nathaniel et al., 2021). Under such circumstances, the global economies have preferred to employ relatively cleaner fossil fuels to generate the national outputs. Consequently, several of the world economies have turned to natural gas as an alternative to the traditionally consumed fossil fuels which are comparatively harmful to the environment (Dong et al., 2018; Xu & Lin, 2019). As a result, natural gas has become an essential feature of the international energy mix and is widely used for residential (Rehman et al., 2020a), commercial (Rehman & Deyuan, 2018a), and farming (Chandio et al., 2019) purposes. Besides, natural gas is also used for electricity generation purposes (Rehman & Deyuan, 2018b). It is an excellent electricity production option due to its adequate thermal productivity and low capital expenses (Apergis & Payne, 2010).

Natural gas, like most other fossil fuels, contains hydrocarbon and therefore combustion of natural gas emits greenhouse gases (GHG) into the atmosphere. Although utilization of unprocessed natural gas stimulates the emissions of large volumes of carbon dioxide (CO₂) and other GHG, combustion of dry natural gas releases relatively less amount of such gases into the atmosphere. This is because, before the delivery of dry natural gas, the hazardous components of unprocessed natural gases are extracted. Hence, compared to oil and coal, natural gas can be considered a low carbon intensity fossil fuel. It is believed that natural gas combustion releases approximately half the amount of CO₂ released from burning coal for generating electricity (Banks, 2003). Consequently, several of the world economies are currently pursuing policies to improve their natural gas consumption levels to reduce their energy consumption-induced GHG emissions in order to comply with their commitments under the Paris Agreement and the Sustainable Development Goals (SDG) agenda of the United Nations (Percebois, 2008; Apergis & Payne, 2010). Besides, since GHG emissions have been acknowledged to hamper economic growth (Rehman et al., 2021), it is pertinent to consume relatively cleaner energy resources to simultaneously ensure economic and environmental well-being (Rehman et al., 2021).

Since all energy resources are not homogeneously composed, their overall impacts on output can be expected to vary as well. However, overlooking the possible heterogeneity of the growth impacts associated with uses of different energy sources, the existing studies in the literature traditionally scrutinized the causal associations between aggregate energy use and gross domestic product (Ozturk, 2010; Payne, 2010). But, assessing the cumulative energy use-economic growth relationship may not account for the different impacts related to different kinds of energy resources consumed by the end-users and within the economic sectors (Payne, 2010). Moreover, it may also lead to erroneous strategy implications for each energy resource (Siddiqui, 2004; Payne, 2010). Hence, it is pertinent to conduct disaggregated analyses to explore the dissimilar impacts of different energy sources on economic growth (Lee & Chang, 2005; Ozturk, 2010; Solarin & Shahbaz, 2013).

Although a significant proportion of the existing studies have scrutinized the total energy consumption-economic growth nexus, empirical work on the impacts of natural gas use on economic growth are minimal. Against this backdrop, this study aims to evaluate the natural gas consumption-economic growth nexus, controlling for financial development, in the context of Pakistan using annual frequency data spanning from 1965 to 2019. Traditionally, Pakistan has been largely fossil fuel-dependent (Irfan et al., 2020b). In Pakistan, 47% of primary energy demand is fulfilled by natural gas and is considered the primary fuel. Since 2000, both petroleum and natural gas have collectively functioned as primary energy inputs for the power plants in Pakistan (Shahbaz et al., 2013). Figure 1 illustrates the trends in the shares of different energy resources in Pakistan's aggregate electricity output figures. However, following the increasing oil prices in the international markets, oil consumption in Pakistan is on the decline, especially due to the transport sector gradually transitioning from being petroleum-intensive to natural gas-intensive. Besides, the government of Pakistan also promotes the use of compressed and liquefied natural gases within the power and transport sectors; these two sectors account for about 51% and 40% of overall natural gas usage, respectively (Shahbaz et al., 2013). Hence, it can be hypothesized that natural gas consumption does play a critically important role in determining the growth of the Pakistan economy. Hence, the objective of this study is to unearth relevant economic growth policies for Pakistan in order to enable the nation to sustain its macroeconomic achievements in the future.

Figure 1: The trends in Pakistan electricity outputs generated using different energy sources

Note: Renewables contain both hydroelectricity and other renewables

Source: World Development Indicators (World Bank, 2020)

This current study contributes to the energy consumption-economic growth narrative for the case of Pakistan in several ways. Firstly, the existing studies that have explored the impacts of energy consumption on Pakistan's economic growth have used the conventional linear modeling methods which specifically evaluated the impacts of positive shocks to energy consumption on the nation's GDP level (Rehman et al., 2019b; 2020b). However, it is believed that the non-linear asymmetric techniques have more predictive control than the linear symmetric techniques (Melike et al., 2015). Hence, this study addresses this issue by using the nonlinear auto-regressive distributed lag (NARDL) method to model the energy use-economic growth nexus in Pakistan. It is asserted in the literature that the NARDL model is superior to the conventionally used auto-regressive distributed lag (ARDL)

model since it predicts the effects of both positive and negative shocks to the explanatory variable on the outcome variable (Neog & Yadava, 2020; Rehman et al., 2021). Furthermore, the NARDL technique is also believed to account for the short-run volatilities and structural break issues in the data. Secondly, the literature is overwhelmingly saturated with studies that have probed into the overall impacts of energy use on the Pakistan economy (Latief & Lefen, 2019; Abbasi et al., 2021). In contrast, only a few of the preceding studies have used the NARDL method to isolate the heterogeneous effects of different energy resources, natural gas in particular, on Pakistan's economic growth indicators. Lastly, this study controls for structural break issues in the data within the analysis to safeguard the unbiasedness of the outcomes. The majority of the previous studies have overlooked the structural break concerns and therefore the evidence documented can be presumed to be inefficient and biased to some extent. In this regard, this study addresses this issue by firstly using the second-generation unit root and cointegration methods to ascertain the stationarity and cointegration properties of the variables of concern. Besides, the application of the NARDL method further neutralizes the structural break impacts within the short-and long-run elasticity estimation processes.

The rest of the manuscript is prepared as follows. Section 2 provides an outline of the trends in Pakistan's economic growth, natural gas consumption, and financial development. The previous relevant studies in the literature are then summarized in section 3. Section 4 explains the methodology used while section 5 reports the empirical results obtained from the analysis. Finally, section 6 concludes by recommending key policies as per the results found in this study.

2. An overview of Pakistan's economic growth, natural gas use, and financial development

The trends in Pakistan's annual GDP per capita and natural gas consumption figures are illustrated in Figure 2. Referring to economic growth, Pakistan is a lower-middle-income South Asian nation. It can be seen that the GDP per capita of Pakistan has, by and large, progressed steadily over the 1965-2019 period. Until 1996, the economy of Pakistan was growing steadily after which the GDP per capita figures somewhat declined and stagnated. However, from 2020 onward, the GDP per capita figures surged again implicating that the nation's economic reforms in the early 2000s managed to uplift the economic conditions to a large extent. As far as the natural gas consumption trends are concerned, the trends implicate that much like the nation's progressive trend in GDP per capita, Pakistan's natural gas consumption also depicts a rising trend. However, during the 1965-1988 period, the average annual growth rate of the natural gas consumption figures was relatively lower than the corresponding average growth rate of GDP per capita. Nevertheless, from 1999 onwards, the average trends in the growth rate of both these figures started to converge which gives the impression that utilization of natural gas in Pakistan does play a central role in determining its economic progress.

Figure 2: Trends in GDP per capita and natural gas consumption (1965-2019)

Source: World Development Indicators (World Bank 2020)

On the other hand, since our analysis also controls for financial development within the Pakistan economy, it is pertinent to have an understanding of the financial development trends as well. The level of financial development within an economy is often measured in terms of the percentage share of the value of domestic credit extended to the private sector in the GDP (Li et al., 2021). Figure 3 illustrates the trends in Pakistan's financial development and annual GDP per capita figures. It can be seen that financial development in Pakistan has more or less matched the corresponding trends in the nation's GDP per capita since both the line graphs depict similar movements. Hence, it can be hypothesized that financial development, much like natural gas consumption, does influence the growth rate of the Pakistani economy.

Figure 3: Trends in financial development and GDP per capita growth rates (1965-2019)

Source: World Development Indicators (World Bank 2020)

2. Literature review

In this section, we first summarize the existing studies which have scrutinized the energy consumption-economic growth nexus. Then, we summarize the studies which have documented evidence regarding the impacts of natural gas use on economic growth. Lastly, we summarize the studies on financial development and economic growth.

2.1. The literature on energy consumption and economic growth

In general, the aggregate energy consumption-economic growth nexus has been causally analyzed under four hypotheses: growth, conservation, feedback, and neutrality hypotheses (Ozturk, 2010; Ozcan & Ozturk, 2019). Firstly, the growth hypothesis refers to the phenomenon that energy consumption stimulates economic growth. Secondly, the conservation hypothesis refers to economic growth influencing the energy consumption levels; thus, this hypothesis advocates in favor of conserving energy for future use. Thirdly, the feedback hypothesis refers to economic growth and energy use being interdependent; thus, implicating that these variables influence one another. Lastly, the neutrality hypothesis asserts that there is no causal relationship between economic growth and energy consumption. The existing studies have evaluated the energy consumption-economic growth nexus through the prism of these four hypotheses using both panel and time-series data. However, traditionally the aggregate energy consumption levels were used to evaluate the impacts of energy use on growth. In a relevant study on Sub-Saharan African countries, Akinlo (2008) found evidence of the feedback hypothesis holding for the cases of Gambia, Ghana, and Senegal, the conservation hypothesis for Sudan and Zimbabwe, and the neutrality hypothesis for Cameroon, Cote D'Ivoire, Nigeria, Togo, and Kenya. In other country-specific studies, Odhiambo (2009) and Tang et al. (2016) reported that the growth hypothesis holds for Tanzania and Vietnam, respectively. As far as panel data evidence is concerned, Ouedraogo (2013) considered the Economic Community of West African States (ECOWAS) and found that economic growth causally influences the energy consumption level in the short-run while energy consumption influences economic growth in the long-run.

Besides, cleaner energy use is said to play a central role in facilitating environmental well-being and therefore sustaining economic growth, whereby researchers have emphasized the importance of investing in clean energy development projects (Ma et al., 2021). Therefore, keeping into consideration the contrasting impacts of clean and unclean energy use on economic growth, several of the existing studies have also disaggregated the energy consumption-economic growth analysis by isolating the effects of non-renewable and renewable energy consumption on economic growth. Inglesi-Lotz (2016) claimed that a rise in the renewable energy consumption level and its share in the total energy consumption level contribute to higher economic growth in the case of a panel of Organization for Economic Cooperation and Development (OECD) countries. Recently, Shahbaz et al. (2020) used data from 38 high-renewable energy-consuming countries and found high levels of renewable energy use resulting in higher levels of economic growth. Similar results were found in another study on 29 OECD countries by Gozgor et al. (2018). Besides, the authors also asserted that non-renewable energy consumption also stimulates growth in these selected OECD nations. In another study by Ivanovski et al. (2021), the authors argued that both renewable and non-renewable energy consumption stimulate economic growth in non-OECD countries but in the context of the OECD nation, only non-renewable energy consumption was evidenced to facilitate economic growth. Recently, in the context of Vietnam, Ha and Ngoc (2020) verified a bidirectional association between non-renewable energy consumption and economic growth. Apart from isolating the impacts of non-renewable and renewable energy use on economic growth, several of the existing studies have further disaggregated the energy consumption-economic growth analysis by scrutinizing the growth impacts associated with different non-renewable and renewable resources. Since this current study is interested in examining the natural gas consumption-economic growth nexus, only the preceding studies in this regard are summarized in the next sub-section.

2.2. The literature on natural gas consumption and economic growth

There is a limited amount of analysis on the relationship between natural gas consumption and economic growth in the literature. Usually, the research on the causal relationships between natural gas use and economic growth can be separated into two sections. A time-series data study (Shahbaz et al., 2013; Siddiqui, 2004; Solarin & Shahbaz, 2015) was performed in the first literature collection. The second comparatively smaller collection of literature based on panel data model analysis (Apergis & Payne, 2010; Asghar, 2008; Melike E. Bildirici & Bakirtas, 2014; Fatai, Oxley, & Scrimgeour, 2004; Furuoka, 2016; Hossein, Yazdan, & Ehsan, 2012; Kum, Ocal, & Aslan, 2012; Ozturk & Al-Mulali, 2015; Pirlogea, 2012). Some of them have used a set of co-integration tools, for example (Gregory & Hansen, 1996; Hansen & Seo, 2002; Søren Johansen, 1988; Søren Johansen & Juselius, 1990; Pesaran, Shin, & Smith, 2001a; Robert & Granger, 1987) to scrutinize the relationship without a causal analysis (Adeniran, 2009; Hu & Lin, 2008; Işık, 2010a; Khan & Ahmad, 2008; Shahbaz et al., 2013; Shahiduzzaman & Alam, 2014). Consequently, the assumptions made in relationship with the presence of natural gas-led production or else become debatable. Even so, the co-integration test only shows the existence of causality but ignores the direction. Unexpectedly, only a few of the preceding studies have conducted cointegration analysis (Granger, Hasaio, Toda, and Yamamoto) to examine the causative relationship between the use of natural gas and economic expansion (Apergis & Payne, 2010; Melike E. Bildirici & Bakirtas, 2014; Das, McFarlane, & Chowdhury, 2013; Hossein et al., 2012; Işık, 2010b; Kum et al., 2012; Lee & Chang, 2005; Pirlogea, 2012; Siddiqui, 2004; Yang, 2000).

In a study by Galadima & Aminu (2020), the authors claimed that natural gas consumption boosts economic growth in Nigeria. Besides, the authors verified this claim using non-linear estimation techniques and concluded that the natural gas consumption-economic growth nexus is non-linear. Similarly in the context of African nations, Awodumi and Adewuyi (2020) found that increasing natural gas consumption is not only effective in enhancing economic growth in Gabon but is also efficient in mitigating environmental pollution. However, in the context of Nigeria, natural gas consumption was argued to exhibit growth-inhibitory impacts. On the other hand, in the context of Egypt, the authors stated that natural gas consumption exerts negligible economic growth impacts. In another study on the Group of Seven (G7) countries, Kum et al. (2012) opined that natural gas consumption influences economic growth for the case of Italy but in the context of the United Kingdom economic growth was found to causally influence the natural gas consumption level. Besides, for Germany, the United States, and France natural gas and economic growth were found to causally influence one another.

Ozturk and Al-Mulali (2015), in the context of selected Gulf Cooperation Council (GCC) countries, stated that promoting natural gas consumption can be an effective means of boosting the economic growth levels of the countries of concern. Moreover, the causality findings revealed a bi-directional causal association between natural gas use and economic growth. In a country-specific analysis in the context of Tunisia, Farhani et al. (2014) concluded that natural gas consumption enhances economic growth. Similarly, Heidari et al. (2013) recommended liberalization of natural gas prices to facilitate higher consumption of natural gas in Iran which, in turn, was claimed to be necessary for stimulating the growth of the Iranian economy. On the other hand, considering the gross capital formation as an indicator of economic growth, Etokakpan et al. (2020) stated that natural gas consumption and economic growth are mutually influenced; thus, a feedback relationship was ascertained. Table 1 summarizes the other relevant country-specific and panel studies, including Pakistan, that have shed light on the relationship between natural gas consumption and economic growth.

Table 1: Literature review (2015-2020) regarding natural gas consumption and economic growth

Author	Country	Variable	Method	Finding
Country-specific studies				
(Shahbaz et al., 2013)	Pakistan	NGC, GDP, Labor, Capital, Export	ARDL, Johansen, Decomposition variance	Growth
(Siddiqui, 2004)	Pakistan	NGC, RGDP	ARDL	Neutrality

2004)			Hsiao's Granger Causality Test	
(Aqeel & Butt, 2001)	Pakistan	GC, RGDP	Egle and Granger,	Neutrality
(Khan & Ahmad, 2008)	Pakistan	RGDP, CPI, NGC	Hsiao,s granger causality ARDL	Co-integration
(Hassan, Tahir, Wajid, Mahmood, & Farooq, 2018)	Pakistan	GDP,NGC,L,C	Johansen maximum likelihood	Growth
(Shahbaz, Arouri, & Teulon, 2014)	Pakistan	NGC,GDP,Labur,Capital	Granger causality	
(Erdoğan, Gedikli, & Kırca, 2019)	Turkey	GDP, NGC	ARDL,	Complement
(Farhani & Rahman, 2019)	France	NG,C,L,GDP	Causality test	Unidirectional
(Solarin & Shahbaz, 2015)	Malaysia	FDI,NGC,GDP,TO	Causality test	
			Granger causality	Feedback
			ARDL	Feedback
Panel studies				
(Aydin, 2018)	Ten natural gas-consuming countries	GDP,NG,GCF,TO	Granger causality	Growth
(Chang et al., 2015)	G7	GDP, NG	Granger causality	Neutrality
(Destek, 2016)	26-OECD	GDP,GCF,NGC,TO	FMOLS,DOLS,VECM	Feedback
(Fadiran, Adebusuyi, & Fadiran, 2019)	12-Euro	GDP,GCF,NG,L,TO	VECM	Growth and Conservative

(Furuoka, 2016)	China, Japan	GDP,NGC,GCF,Export	ARDL	Growth
(Jahangir & Dural, 2018)	Caspian Sea region	COEX,COP,COPRO,COR,GDP,NGEX,NGP,NGPR O,NGR	OLS, Granger causality	Unidirectional
(Solarin & Ozturk, 2016)	12-OPEC	GDP, NG	Granger causality	Feedback
(Zhi-Guo, Cheng, & Dong-Ming, 2018)	Northeast Asia	C,L,NG,GDP	Causality test	One-way relation

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243 2.3.The literature on financial development and economic growth

244 A significant preponderance of research indicates that the financial sector's growth plays a crucial role in economic
245 growth. It stimulates economic development through capital accumulation and technological development by
246 accelerating savings, rallying and accumulating savings, and generating investment information. Goldsmith (1969)
247 was the first one to prove the clear connection between financial growth and per capita GDP empirically. One reason
248 for this positive relationship is that financial intermediation enhances productivity before increasing
249 investment(Bencivenga & Smith, 1991; Greenwood & Jovanovic, 1990). Many studies provided evidence that there
250 is a positive relationship between financial development indicators and economic growth(Beck & Levine, 2004;
251 Beck, Levine, & Loayza, 2000; King & Levine, 1993; Levine, 1997, 2003; Rajan & Zingales, 1998).In a recent
252 study on Sub-Saharan African nations, Junior Abeka (2021) concluded that economic growth in these African
253 countries is conditional on the development of their respective financial sectors. Besides, the authors also
254 emphasized that information and communications technology enhances the favorable growth impacts associated
255 with financial development in Africa.In another study on Brazil, Russia, India, China, and South Africa (BRICS),
256 Raghutla and Chittedi (2020) also asserted financial development exerts positive economic growth effects on these
257 emerging economies. Conversely, as opposed to the findings of the abovementioned studies, Kapaya (2020) argued
258 that financial development is yet to be effective in boosting economic growth in Tanzania; rather the financial
259 development policies have hampered the growth of the Tanzanian economy. Similarly, Raheem et al. (2020) also
260 found evidence of financial development dampening growth in the case of the G7 countries.While all these studies
261 emphasize the linear relationship between financial and economic development, several studies have also scrutinized
262 the nonlinearity of this nexus. Few studies indicate that financial development has a positive relationship with
263 economic growth for values above the threshold(Deidda & Fattouh, 2002; Rioja & Valev, 2004), whereas others
264 document inverse results (Arcand, Berkes, & Panizza, 2015; Cecchetti & Kharroubi, 2012; Ergungor, 2008; Law &
265 Singh, 2014; Shen & Lee, 2006). Apart from directly contributing to economic growth, several studies have also
266 claimed that financial development improves environmental quality which, in turn, can indirectly help to sustain the
267 economic growth performances (Qin et al., 2021).

268 3. Methodology and data

269 3.1. Data

The dataset in the current study includes the data on annual GDP, natural gas consumption, and financial development in the context of Pakistan.

The GDP figures are the annual total market value of the goods and services produced within Pakistan for each year between 1965 and 2019. The natural gas consumption figures are annual volumes of natural gas consumed for different purposes within the Pakistan economy. Lastly, financial development is proxied by the domestic credits extended by the commercial banks as a percentage share in the GDP of Pakistan for the respective year. Table 2 shows the units of measurement and corresponding data sources of these variables.

Table 2. Variables and sources

Variables	Units	Sources	References
GDP	United States dollars	World Development Indicators BP Statistical Review of World	(Shahbaz et al., 2013)
NGC	Billion cubic meters	Energy	(Solarin & Ozturk, 2016)
FD	% of GDP	World Development Indicators	(Neog & Yadava, 2020)

3.2. Empirical model

Following Neog & Yadava (2020), we model the economic growth of Pakistan as a function of natural gas consumption and financial development which can be shown as:

$$\ln GDP_{pc_t} = f(\ln NGC_t, FD_t) \quad (1)$$

Equation 1 can be specified in its linear form as:

$$\ln GDP_{pc_t} = \beta_0 + \beta_1 \ln NGC_t + \beta_2 FD_t + \mu_t \quad (2)$$

where the subscript t refers to the time period considered in this study ($t=1965, 1966, \dots, 2019$). In equation (2), GDP_{pc} refers to the gross domestic product per capita (used to proxy for economic growth in Pakistan), NGC stands for natural gas consumption level, and FD is the percentage share of credit extended to the private sector in the GDP of Pakistan (used to proxy for financial development). The parameters $\beta = (\beta_0, \beta_1, \beta_2)$ are the parameters to be estimated. The variables GDP and NGC are transformed into their natural logarithms to predict the elasticity parameters.

According to the conventional econometric methodology, the long-term and short-term links between two or more variables are determined using the ARDL error-correction model. This estimation technique considers the linear association among the variables and ignores the non-linearity aspect. Contemplating the recent non-linear existence of the variables, Shin et al. (2014) expanded the ARDL bounds testing cointegration technique of Pesaran et al. (1999; 2021b) and introduced the asymmetrical ARDL cointegration method. This approach is competent in displaying short-run volatilities and asymmetries. The specific asymmetric long-run equation of our empirical model (Equation 2) can be shown as:

$$\ln GDP_{pc_t} = a_0 + a_1 \ln NGC_t^+ + a_2 \ln NGC_t^- + a_3 FD_t^+ + a_4 FD_t^- + \varepsilon_t \quad (3)$$

In equation (3), NGC_t^+ , NGC_t^- , FD_t^+ and FD_t^- are the positive and negative shock components of natural gas consumption and financial development, respectively:

$$\begin{cases} NGC_i^+ = \sum_{i=1}^t \Delta NGC_i^+ = \sum_{i=1}^t \text{MAX}(\Delta NGC_i, 0) \\ NGC_i^- = \sum_{i=1}^t \Delta NGC_i^- = \sum_{k=1}^t \text{MIN}(\Delta NGC_i, 0) \end{cases} \quad (4)$$

$$\begin{cases} FD_i^+ = \sum_{i=1}^t \Delta FD_i^+ = \sum_{i=1}^t MAX(\Delta FD_i, 0) \\ FD_i^- = \sum_{i=1}^t \Delta FD_i^- = \sum_{i=1}^t MIN(\Delta FD_i, 0) \end{cases} (5)$$

Following the Equation (2), in the NARDL model can be specified as:

$$\begin{aligned} \Delta \ln GDP_{pc_t} = & \beta_0 + \beta_1 \ln GDP_{pc_{t-1}} + \beta_2 \ln NGC_{t-1}^+ + \beta_3 \ln NGC_{t-1}^- + \beta_4 FD_{t-1}^+ + \beta_5 FD_{t-1}^- + \\ & \sum_{i=1}^m \delta_{1i} \Delta \ln GDP_{pc_{t-1}} + \sum_{i=1}^n \delta_{2i} \Delta \ln NGC_{t-1}^+ + \sum_{i=1}^p \delta_{3i} \Delta \ln NGC_{t-1}^- + \sum_{i=1}^q \delta_{4i} \Delta FD_{t-1}^+ + \\ & \sum_{i=1}^r \delta_{5i} \Delta FD_{t-1}^- + \mu_i (6) \end{aligned}$$

In equation (6), we put m, n, p, q, and r as lags orders. But, $\beta_1, \beta_2, \beta_3, \beta_4$, and β_5 represent long-term positive and negative coefficient effects of NGC and FD on GDP per capita. $\sum_{i=1}^n \delta_{2i}, \sum_{i=1}^p \delta_{3i}, \sum_{i=1}^q \delta_{4i}$ and $\sum_{i=1}^r \delta_{5i}$ consider the short-run positive and negative impacts of NGC and FD on GDP, correspondingly. In this paper, by applying the NARDL technique, the non-linear long-run link is captured.

3.3. Econometric methodology

The econometric analysis begins by checking for the order of integration among the variables. It is important to check this order because both ARDL and NARDL methods can handle variables integrated at either level, I(0), or first difference, I(1), but not second difference, I(2). This model has only one drawback since it cannot proceed in event of the variables being integrated at second (Ibrahim, 2015). Hence, firstly we apply the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) root unit tests. However, since these tests cannot control for the structural break issues within the estimation process, we use the Zivot-Andrews (1992) unit root with structural break test to ascertain the integrating properties of the variables. The unit root analysis is followed by the cointegration analysis. In the next step, we evaluate the cointegration among the variables as a pre-requisite to predicting the long-run coefficients. In this regard, we use the bounds test to check whether cointegration occurs. Besides, to check for the cointegrating properties by accommodating the structural break issue within the estimation process, we use the Gregory-Hansen (1996) cointegration test.

After checking that co-integration, we apply the NARDL approach to predict the effects of positive and negative shocks to natural gas consumption and financial development (NGC_t^+, NGC_t^-, FD_t^+ , and FD_t^-) on economic growth in Pakistan. The nonlinear effects of a 1% change in the NGC_t^+, NGC_t^-, FD_t^+ and FD_t^- are assessed respectively as:

$$\begin{cases} S_h^+(lnNGC) = \sum_{j=0}^h \frac{\partial \ln GDP_{pc_{t+1}}}{\partial \ln NGC_{t-1}^+} \\ S_h^-(lnNGC) = \sum_{j=0}^h \frac{\partial \ln GDP_{pc_{t+1}}}{\partial \ln NGC_{t-1}^-} \end{cases} (7)$$

$$\begin{cases} S_h^+(FD) = \sum_{j=0}^h \frac{\partial \ln GDP_{pc_{t+1}}}{\partial FD_{t-1}^+} \\ S_h^-(FD) = \sum_{j=0}^h \frac{\partial \ln GDP_{pc_{t+1}}}{\partial FD_{t-1}^-} \end{cases} (8)$$

Lastly, we apply the Hacker-Hatemi-J (2012) causality test to predict the causal relationships between the variables of concern. Figure 4 illustrates the econometric methodology considered in this study.

4. Empirical results

The summary statistics of the variables are presented in Table 3. It can be seen that all three variables are negatively skewed and also platykurtic. Besides, the Jarque-Bera statistics show the normality of the distribution of the variables.

Table 3: Summary statistics

Descriptive statistics	lnGDPpc	lnNGC	FD
Mean	4.022	1.036	22.877
Median	4.026	1.042	23.823
Maximum	5.243	1.659	29.786
Minimum	2.743	0.169	15.305
Std. Dev.	0.777	0.438	3.607
Skewness	-0.242	-0.232	-0.408
Kurtosis	1.787	1.862	2.396
Jarque-Bera	3.388	3.463	2.362
Probability	0.183	0.176	0.306
Observations	55	55	55

The ARDL model can handle variables that are stationary at either level or first difference or both. Hence, the ADF, PP, and Zivot-Andrews unit root tests were used and the results of the three tests are shown in Table 4. The unit root findings, both considering and not considering structural break issues, reveal that all the variables are not stationary at $I(0)$ but stationary at the $I(1)$; thus, it is verified that none of the variables is stationary at $I(2)$. Therefore, the NARDL technique can be applied. The unit root analysis is followed by the cointegration analysis.

Table 4: Unit root test results

Variable	ADF	PP	Zivot-Andrews
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Considering Break	No		No		Yes	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
lnGDPpc	-0.653	-6.302***	-0.653	-6.279***	-4.190 (1993)	-8.830*** (1991)
lnNGC	-2.547	-5.140***	-2.247	-4.996***	-4.230 (2006)	-5.690*** (2003)
FD	-1.923	-6.258***	-2.150	-6.224***	-4.126 (2011)	-7.279*** (2009)

Note: The locations of the structural breaks from the Zivot-Andrews analysis are given in the parentheses. *** denotes statistical significance at 1% level.

For the ARDL bounds test, we calculate equation (6) using a general-to-specific method and alphabets $p = q = 2$ as the optimal lag period. This groundbreaking method was also accompanied by (Shin et al., 2014) to finalize the asymmetrical ARDL model. According to the general-to-specific technique, we include only the significant lagged repressors because insignificant lagged regressors can interfere in dynamic multipliers (Katrakilidis & Trachanas, 2012). Additionally, we also perform the Gregory-Hansen test to account for the structural break issue within the cointegration analysis. The cointegration test results are reported in Table 5. From the estimated F-statistic from the bounds test, we can see that the value of the F-statistic is above the lower and upper bound critical values at 1% levels of significance. Thus, the null hypothesis of non-cointegration is rejected to affirm cointegrating relationships between economic growth, natural gas consumption, and financial development in Pakistan. Similarly, the statistical significance of the ADF, Zt, and Za statistics from the Gregory-Hansen test also affirm the presence of cointegrating equations in the model. Hence, it can be said that economic growth in Pakistan has long-run associations with natural gas consumption and financial development level. Consequently, the NARDL analysis is conducted to ascertain the long-run elasticities of economic growth.

Table 5: Cointegration test results

Panel A: Bounds test			
Equation	F-stat.		
lnGDPpc=f(lnNGC,FD)	15.066***		
Critical values	Upper bound, I(1)	Upper bound, I(1)	
10%	2.2	3.09	
5%	2.56	3.49	
2.50%	2.88	3.87	
1%	3.29	4.37	
Panel B: Gregory-Hansen test (with structural break)			
Equation	ADF stat.	Zt stat.	Za stat.
lnGDPpc=f(lnNGC,FD)	-7.35*** (1991)	-7.41*** (1991)	-59.66**

Note: The locations of the structural breaks from Gregory-Hansen analysis are given in the parentheses. *** and ** denote statistical significance at 1% and 5% level, respectively.

Table 6 presents the short- and long-term asymmetric relationships between the variables of concern. In the short-run, only a positive shock to natural gas consumption is seen to boost economic growth in Pakistan. The elasticity estimate shows that a 1% change in positive shock to natural gas consumption would account for a 0.11% rise in Pakistan's per capita GDP figures in the short-run. Besides, the negative shocks to natural gas consumption are found to be ineffective in influencing the economic growth level in the short-run. Similarly, both positive and negative shocks to financial development are seen to be ineffective in affecting the economic growth level of Pakistan in the short-run. On the other hand, in the long-run, a positive shock to the natural gas consumption level boosts Pakistan's per capita economic growth level. The elasticity estimate shows that a 1% change in positive shock to natural gas consumption would account for a 0.198% rise in Pakistan's per capita GDP figures. Alternatively, negative shocks to the natural gas consumption level are found to dampen economic growth in Pakistan. The

corresponding elasticity parameter denotes that a 1% rise in the negative shock to natural gas consumption level would account for a decline in the per capita GDP level by 0.818%. Therefore, these findings imply that natural gas is a major determinant of growth for Pakistan whereby the nation needs to ensure a sufficient supply of natural gas to sustain its growth achievements in the future. Our results are in line with Shahbaz et al. (2013), Solarin & Ozturk (2016). On the other hand, the elasticity estimates also reveal that positive shocks to the financial development figures inhibit economic growth in Pakistan. A rise in the positive shock to the share of credit extended to the private sector in the GDP accounts for a decline in the per capita GDP figures of Pakistan by 0.004%. Similarly, negative shocks to the financial development level also dampen the growth figures of Pakistan. A 1% rise in the negative shocks to the share of credit extended to the private sector in the GDP triggers a decline in the per capita GDP level by 0.001%. Hence, it can be said that the relationship between economic growth and financial development in the context of Pakistan is non-linear.

Table 6: Long-run results from the NARDL analysis

Variable	Short-run	Long-run
LnNGC_POS	0.105*	0.198***
LnNGC_NEG	0.500	0.818***
FD_POS	-0.001	-0.004***
FD_NEG	0.005	0.002***
D(1991)	-1.160***	-1.709***
C	0.133***	0.390***

Note: *** denotes statistical significance at 1% level; The variable D(1991) is the dummy variable that accounts for the structural break location identified from the cointegration analysis.

The presence of asymmetries among natural gas consumption, economic growth, and financial development are verified using the Wald test. The corresponding outcomes from the Wald Test are shown in Table 7. The results show the asymmetries between the variables used in this study. The results indicate that the impact of natural gas consumption and financial development followed the asymmetric relationship.

Table 7: Asymmetric results

Variable	Wald stat.	P-value
lnGDPpc and lnNGC	4.114***	0.000
lnGDPpc and FD	3.510***	0.000

Note: *** denotes statistical significance at 1% level.

We have further investigated some necessary diagnostic tests, such as normality of residual, serial correlation, and heteroskedasticity. The corresponding results, as shown in Table 8, indicate that there are no autocorrelation issues in our model since the estimated LM statistic is statistically insignificant. Besides, the Ramsey RESET test statistic confirms that the model is well-specified. On the other hand, the outcome from the ARCH tests suggests that there are no heteroscedasticity concerns either. Furthermore, the J-B normality test finding shows that the residuals are normally distributed. At the same time, the stability of the predicted elasticity parameters is checked using the Cumulative Sum of Squares (CUSUM) and Cumulative Sum of Squares Squared (CUSUMSQ) tests. The outcomes, as illustrated in Figure 5, confirm the stability of the estimated results from the NARDL analysis.

Table 8: Diagnostic tests results

Test	Statistics	Prob.
LM	1.401341	0.4963
J-B	4.881434	0.2997
ARCH	0.120277	0.7287
RESET	1.007128	0.3206

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434 Finally, the Hacker-Hatemi-J causality test is performed to evaluate the causal associations. The causality results, as
 435 reported in Table 9, reveal unidirectional causality running from natural gas consumption to the per capita GDP
 436 level in Pakistan. On the other hand, no causal relationship between economic growth and financial development
 437 could be established from the causality analysis.

438

Table 9: The causality test results

Null Hypothesis	MWALD stat.	Critical values			Decision
		1%	5%	10%	
$\ln\text{NGC} \rightarrow \ln\text{GDPpc}$	8.334***	7.455	4.120	2.879	Unidirectional causality between $\ln\text{NCG}$ to $\ln\text{GDppc}$
$\ln\text{GDPpc} \rightarrow \ln\text{NGC}$	2.145	7.320	4.100	2.840	
$\text{FD} \rightarrow \ln\text{GDPpc}$	2.550	7.298	4.150	2.850	No causality between $\ln\text{GDPpc}$ and FD
$\ln\text{GDPpc} \rightarrow \text{FD}$	2.140	7.410	4.161	2.888	

439 Note: $\rightarrow$ denotes does not Granger cause. *** denotes statistical significance at 1% level.

440

5. Conclusion and policy implications

441 Ensuring energy security is pertinent for sustaining economic growth, especially in the context of the developing
 442 nations which are largely energy-starved. Besides, these countries are also overwhelmingly reliant on fossil fuels for
 443 generating the national output. However, given the associated environmental concerns, it is recommended that
 444 developing nations enhance the consumption of relatively cleaner energy resources. Against this background, this
 445 study aimed to evaluate the asymmetric impacts of natural gas consumption and financial development on Pakistan's
 446 economic growth over the 1965-2019 period. The findings from the cointegration analysis confirmed long-run
 447 associations between economic growth, natural gas consumption, and financial development in Pakistan. The

NARDL estimates revealed that in the short-run only positive shocks to natural gas consumption level positively affect the per capita GDP level of Pakistan. On the other hand, in the long-run, positive and negative shocks to natural consumption levels are found to increase and decrease the per capita GDP level of Pakistan, respectively. On the other hand, both positive and negative shocks to financial development were found to inhibit the growth of the Pakistan economy. Furthermore, the causality estimates validate the growth hypothesis by verifying a unidirectional causality stemming from natural gas consumption to economic growth. In line with these findings, several policy suggestions can be put forward.

Firstly, the government should adopt policies to enhance the natural gas extraction rates to increase the indigenous natural gas supplies. Additionally, it is also pertinent to invest in projects for the development of technology that is required to enhance the natural gas extraction rates. Furthermore, keeping both economic and environmental sustainability into consideration, the government should incentivize the private sector to invest in the energy sector, especially for enhancing the share of natural gas-fired electricity output in Pakistan's total electricity output figures. Secondly, the government needs to restructure the existing financial development policies in order to phase out the associated growth-inhibitory impacts. Ideally, it is essential for enhancing access to credit for the private investors who are keen to invest in high-growth-contributing sectors. Simultaneously, greater provision for credit should be introduced for the private sector to come forward to invest in the energy sector, especially to enhance the natural gas supplies. This would not only facilitate the growth of the Pakistan economy but would also indirectly enhance growth by boosting the natural gas consumption level.

Data limitation was the only constraint faced in conducting this study. Consequently, relevant variables could not be included in the model. Besides, this current study can be extended in several ways. First, the present paper can be extended to include other dependent variables like CO₂ emission, renewable energy production and consumption, trade openness and technical factors, etc. to assess the impacts of natural gas consumption and financial development on these macroeconomic variables. Second, panel studies can be conducted in the context of South Asian countries including Pakistan. Third, different econometric techniques can be applied for a robustness check of the findings from this study.

Declarations

-Ethical Approval: Not applicable

-Consent to Participate: Not applicable

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-Authors Contributions: HMS conceptualized, conducted the econometric analysis and wrote the introduction. ZL conceptualized, conducted the econometric analysis and supervised the work. MM analyzed the findings, conducted the literature review, wrote the conclusions and recommendations and compiled the overall manuscript. RA analyzed the findings and wrote the conclusions and recommendations. HM reviewed the literature, discussed the findings, and edited the entire draft.

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