



Research article

Exploring the driving factors of economic growth in the world's largest economies

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ABSTRACT

This study explores the main factors of economic growth in a panel of the world's 20 biggest economies considering the data period of 39 years (1980–2018). In particular, the roles of international trade, energy use, human capital, and foreign direct investment (FDI) are examined in addition to the roles of capital and labour. To estimate the results the panel autoregressive distributed lag (ARDL) method of Pool Mean Group (PMG) estimator and heterogeneous panel causality test are used with due consideration of cross sectional dependence test, cointegration test and other necessary diagnostic tests. The obtained results ratify the cointegration among the variables used. Energy use, trade, capital, labour, human capital development and foreign direct investment have positive and significant impacts on the economic growth of these countries in the long run. In the short run energy use, trade and capital also have positive and significant effects, but human capital has negative effect on economic growth. A bidirectional causal relationship between economic growth and trade, capital, labour and human capital, and a unidirectional causal link from economic growth to energy use and foreign direct investment are also found. The obtained results are theoretically consistent, and therefore have important policy implications.

1. Introduction

Continuous and sustained economic growth is still an unfulfilled aspiration for a number of countries in the world due to prolonged and wide-ranging policy uncertainties. To ensure sustainable economic growth and meet the ambitious targets of the 2030 Agenda for Sustainable Development, a vibrant and inclusive global economy is essential through the formulation and execution of a wide range of policy initiatives (United Nations, 2020). In this regard, all economies require policies facilitating reduction of trade disputes, proper utilization of energy, articulation of suitable human capital formation and appropriate foreign direct investment (FDI). Therefore, determination of factors responsible for economic growth is still a focal point of research for many researchers and policy makers across the globe.

A large number of studies (e.g. Shahbaz and Rahman, 2010; Omri and Kahouli, 2014; Pelinescu, 2015; Busse and Koeniger, 2015; Rahman and Mamun, 2016; Rahman et al., 2017; Rahman et al., 2019; Diebolt and Hippe, 2019) have endeavoured to identify the growth factors but the

results have been ambiguous. This lack of certainty may be due to the heterogeneous nature of countries, use of differing methodologies, variation of data periods and failure to select the right variables. Therefore, further study is needed to provide proper policy insights. Our current study is an endeavour to conduct an experiment about the role of energy use, trade, human capital and FDI on economic growth using various sophisticated econometric techniques under the Cobb-Douglas production function framework in the case of a panel of the world's 20 biggest economies.¹ These countries cover 60% of the world's population (4.526 billion out of 7.593 billion), along with 79% of global GDP (US\$65.84 trillion out of US\$82.72 trillion), 60% of world FDI (US\$0.78 trillion out of US\$1.30 trillion), 64% of world trade (US\$31.65 trillion out of US\$49.18 trillion), and 76% of world energy use (10.58 trillion kg of oil equivalent out of 13.86 trillion), which is shown in Table 1 (WDI, 2020; BP, 2019). Thus, our study is inclusive and comprehensive and thus has global significance.

The main motivation for selecting these variables is based on the theoretical/conceptual notion, data availability and past literature. The rationale for choosing these variables is briefly mentioned below.

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E-mail address: alam.khosrul@gmail.com (K. Alam).¹ The countries are Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Netherlands, Russian Federation, Saudi Arabia, Spain, Switzerland, Turkey, United Kingdom and the United States.

Table 1. Statistics of chosen variables of the sample countries in 2018.

Variables	Sample countries	(Figure in trillion)	
		World	% of world
Energy Use (kg of oil equivalent)	10.584	13.865	76.336
International Trade (constant 2010 US\$)	31.647	49.215	64.304
Foreign Direct Investment (net inflows; constant 2010 US\$)	0.785	1.302	60.256
HCI	-	-	-
Capital (Gross capital formation; constant 2010 US\$)	12.546	21.639	57.979
Labour (Total)	0.002	0.003	63.519
GDP (constant 2010 US\$)	65.845	82.893	79.434

Sources: WDI, 2020; BP, 2019.

Energy economists argue that energy is considered to be a significant factor in the production process, like capital and labour, for its growing role in industrial production (Rahman et al., 2019) and this variable has always been used in growth analysis in recent decades (Rahman and Mamun, 2016; Saidi et al., 2017; Azam, 2020; Rahman and Vu, 2020). Trade variables are important inclusions in growth analysis on the grounds that international trade (exports and imports) plays a vital role in specialization, technology diffusion, higher capacity utilization, knowledge spillover effects, industrialization and enhancement of total factor productivity (Krueger, 1990; Rahman et al., 2019). The proponents of endogenous growth theory believe that human capital has a strong role in the economic growth process (Alataş, and Çakır, 2016). Human capital development induces the increase of innovative entrepreneurs, productivity and output, all of which ultimately lead to economic growth (Azam and Ahmed, 2015; Diebolt and Hippe, 2019). FDI also plays a contributory role in economic growth through technology transfer (Borensztein et al., 1998), backward and forward linkages (Rodriguez-Clare, 1996) and boosting exports (Aitken et al., 1999; Azam and Ahmed, 2015). However, the negative impact of FDI is also observed in the literature (Hausmann and Fernandez-Arias, 2001). Hence, the investigation of the true role of this variable is still a necessity.

Against this backdrop, the main contributions of this research are: (i) this is the first ever study in the literature, as far as we know, that explores the impact of trade, energy, human capital and FDI on economic growth considering the biggest 20 economies of the globe; (ii) this study utilizes the most recent available and inclusive data covering a longer period of 39 years (1980–2018); (iii) the results are obtained by applying various sophisticated econometric tools i.e. cross-sectional dependence test, CADF panel unit root test, Pedroni and Kao test, panel autoregressive distributed lag (ARDL) method of Pool Mean Group (PMG), Dumitrescu and Hurlin causality test (details are in section 3.3); (iv) the study has included human capital, an important growth factor, which is generally ignored; (v) the obtained results are confirmed by using different diagnostic tests; and (vi) our findings will provide guidelines to the policy makers to ensure sustained economic growth by adopting a wide range of trade, energy, human capital and FDI policies.

The study is structured in the following order: following the introduction, section 2 reviews the literatures; section 3 describes the model, data and methodology; section 4 displays, discusses and interprets the estimated results; and section 5 draws the conclusion with policy implications.

2. Literature review

2.1. Economic growth-energy use nexus

Energy is widely deliberated as the life blood and engine of modern economic growth but its intermingled impact on the economy has created an enigmatic nexus between them; moreover the 1973 oil crisis promoted the re-thinking of the prevailing energy-growth nexus which led to thoughtful investigations by copious enthusiastic researchers. In this line Kraft and Kraft (1978) heralded the importance of energy consumption on

economic growth in the USA. The subsequent research and empirical evidence identified the direction of causal association between economic growth and energy consumption under four erudite strands for formulating suitable energy policies. These strands are the growth hypothesis, the conservation hypothesis, the feedback hypothesis, and the neutrality hypothesis (Shahbaz et al., 2013, 2018; Saidi et al., 2017; Farhani and Rahman, 2019; Bercu et al., 2019; Rahman and Velayutham, 2020).

The growth hypothesis of economic growth and energy nexus shows the unidirectional causality emanates from energy consumption; energy is considered a vital input for economic growth and functions as a complement of labor and capital in production activities. Apergis and Payne (2010) identified the validation of growth hypothesis from nine South American countries over the period from 1980–2005. Similar observations in the case of the group of countries are drawn out by Dahmardeh et al. (2012) in the context of 10 Asian developing countries, Destek (2016) in case of OECD countries; the confirmation of the growth hypothesis has also been experienced in the case of a single country by Tsani (2010) for Greece, Borozan (2013) for Croatia, and Tang et al. (2016) for Vietnam.

The conservation hypothesis postulates the unidirectional causal relationship derived from economic growth to energy consumption, and this hypothesis is validated by the studies of Dahmardeh et al. (2012) for 10 Asian developing countries, Shahbaz et al. (2018) for the top 10 energy consuming countries, and Rahman and Velayutham (2020) for South Asia. This hypothesis has also been validated for single country studies such as that of Kraft and Kraft (1978) for the U.S.A, Hossain (2013) and Rahman and Kashem (2017) for Bangladesh, and Shahbaz et al. (2017) for India.

The feedback hypothesis considers the bidirectional causal link between economic growth and energy consumption; and the studies of Mutascu (2016) for G7 countries, Saidi et al. (2017) for a panel of 53 countries, Bercu et al. (2019) for central and eastern European countries support this hypothesis. This hypothesis was also confirmed for some individual country studies like Shahbaz et al. (2013) for Indonesia, Islam et al. (2013) for Malaysia, and Farhani and Rahman (2019) for France.

The neutrality hypothesis claims no causal link between economic growth and energy consumption; the evidence of this hypothesis is observed by Wolde-Rufael (2006) for 11 African countries and Chen et al. (2007) for Thailand, Singapore, Indonesia and the Philippines. Payne (2009) and Rahman and Mamun (2016) also found the existence of this hypothesis for the USA, and Australia, respectively.

The above review reveals the evidence of different hypotheses. Therefore, further study on this nexus is still essential to formulate appropriate energy policy for economic growth.

2.2. Economic growth-trade nexus

Although trade is underpinned as the significant pillar of economic growth, there is a relentless debate on economic growth-trade nexus, which facilitated the ample theoretical and empirical investigations. The empirical findings of this nexus are mixed. For example, Were (2015); Busse and Koeniger (2015); Pradhan et al. (2017) and Kebo (2017) found

positive and significant impact of trade on economic growth. In contrast, Musila and Yiheyis (2015), Ali and Abdullah (2015), Kurihara and Fukushima (2016), and Moyo and Khobai (2018) found an inverse or limited support on this relationship. The studies undertaken by Were (2015), Busse and Koeniger (2015) and Pradhan et al. (2017) were conducted on a sample of 85 countries, 108 countries, and the ASEAN countries, respectively. The study conducted by Keho (2017) is on Cote d'Ivoire. The negative effect of trade revealed by Musila and Yiheyis (2015), Ali and Abdullah (2015), and Kurihara and Fukushima (2016), Moyo and Khobai (2018), Rahman et al. (2020) is for Kenya, Pakistan, the global panel, 11 Southern African Development Cooperation (SADC) countries, and South Asia, respectively.

Furthermore, Rahman et al. (2017) observed the bidirectional causal association between economic growth and trade openness in the case of major developing and developed countries. However, Rahman and Mamun (2016) found no long-run cointegration between economic growth and international trade in the context of Australia. Thus, inconclusive and ambiguous outcomes of various literatures demand for further investigation on trade-growth nexus.

2.3. Economic growth-human capital development nexus

The nexus between human capital and economic growth is also inconclusive in the literature. Various researchers have indicated the enormous positive and significant effect of human capital on economic growth; however, a number of other studies have also depicted the opposite relationship between them. The mingled identification of economic growth-human capital nexus was found in the studies of Pelinescu (2015), Azam and Ahmed (2015), Abubakar et al. (2015), Alataş and Çakir (2016), Fashina et al. (2018) and Diebolt and Hippe (2019). Pelinescu (2015) outlined the positive and significant impact of the innovative capacity of human capital and the qualifications of employees but the bewildering negative impact of education expenditure on economic growth in the EU countries. Azam and Ahmed (2015) confirmed the human capital development as critical for economic growth in case of CIS countries. Abubakar et al. (2015) indicated that financial development affects economic growth through the influence of human capital accumulation in the case of the economic community of West African States (ECOWAS), although the direct impact of human capital on economic growth has not been seen. Alataş and Çakir (2016) identified positive and significant effects of both education and health on economic growth in developing countries, and no significant effect in developed countries but the positive effect of education and the negative effect of health on economic growth in the less developed countries. Fashina et al. (2018) stated that economic growth is sensitive to human capital shock through education in Nigeria. Diebolt and Hippe (2019) outlined that the past regional human capital is a driving force to explain the existing regional inequalities in innovation and economic development in the European regions from 1850 - 2010. Because of the controversial and ambivalent findings and the lack of consideration of human capital index data, further work on economic growth-human capital nexus is still alluring.

2.4. Economic Growth-FDI nexus

FDI-economic growth nexus is also not conclusive in the literature. Some researchers drew out a positive and significant nexus (e.g. Rahman and Salahuddin, 2010; Shahbaz and Rahman, 2010; Omri and Kahouli, 2014; and Azam and Ahmed, 2015), while some others perceived overwhelmingly negative associations between economic growth and FDI (e.g. Belloumi and Alshehry, 2018; Bakari and Tiba, 2019). In this context, Rahman and Salahuddin (2010) noted the significant positive impact of foreign direct investment (FDI) on the economic growth in case of Pakistan. Shahbaz and Rahman (2010) also revealed the positive nexus of foreign capital inflows (proxied by FDI) with economic growth in Pakistan. Omri and Kahouli (2014) obtained the bidirectional causality between foreign investment and economic growth in 13 MENA countries;

Azam and Ahmed (2015) obtained the facilitating role of FDI on economic growth in CIS countries; Gherghina et al. (2019) found the non-linear link between FDI and economic growth in 11 Central and Eastern European countries; and Sarker and Khan (2020) identified the positive impact of FDI on economic growth in case of Bangladesh. In contrast, Belloumi and Alshehry (2018) and Bakari and Tiba (2019) ascertained the negative impact of FDI on economic growth in Saudi Arabia and 24 Asian economies, respectively.

From the outcomes of the mentioned literatures, it has been found that the results are inconclusive and not conducive to the articulation of any suitable policy efforts towards sustainable economic growth. Moreover, a detailed and comprehensive study like ours (covering the world's 20 biggest economies) is absent in the literature. Therefore, this research—investigation into the effects of energy use, trade, capital, labour, FDI and human capital—is a useful way to fill up the existing research gap.

3. Model, data and methodology

3.1. Model

The theoretical foundation for exploring the major determinants of economic growth in the World's biggest 20 economies is the neoclassical growth model (Cobb and Douglas, 1928; Solow, 1956) where capital and labour are considered as the main determinants of production activities. The framework of the Cobb-Douglas production function is as follows where technology is assumed constant.

$$Y_{it} = K_{it}^{\alpha_1} L_{it}^{\alpha_2} e^{\mu_{it}} \quad (1)$$

In the above equation, Y is output; K and L represent capital and labour, respectively; e is the error term capturing unobserved variables; and the subscripts i and t, respectively, symbolizes country and time. We have extended this growth model by adding the possible other factors that might affect economic growth. Hence, our augmented growth model for empirical investigation is as follows:

$$GDP_{it} = f(ENG_{it}, TRA_{it}, CAP_{it}, LAB_{it}, FDI_{it}, HCI_{it}) \quad (2)$$

where, GDP is the real gross domestic product per capita (proxy for economic growth), ENG is the per capita energy use (kg of oil equivalent), TRA is the per capita trade (exports + imports) which is estimated total trade at constant 2010 US\$ divided by total population, CAP stands for per capita capital calculated as the gross capital formation at constant 2010 US\$ divided by total population, LAB represents the total labour force, FDI is per capita foreign direct investment is obtained total foreign direct investment (net inflows) at constant 2010 US\$ divided by total population and HCI is the human capital index.

The Eq. (2) can be written as a following linear form:

$$GDP_{it} = \beta_1 ENG_{it} + \beta_2 TRA_{it} + \beta_3 CAP_{it} + \beta_4 LAB_{it} + \beta_5 FDI_{it} + \beta_6 HCI_{it} + \varepsilon_{it} \quad (3)$$

We have transformed all the variables into natural logarithms to reduce the existence of heteroscedasticity and measure the elasticity directly from the slope coefficients. Therefore, the Eq. (3) can be rewritten as a linear natural log form of the production function as:

$$LN GDP_{it} = \beta_1 LN ENG_{it} + \beta_2 LN TRA_{it} + \beta_3 LN CAP_{it} + \beta_4 LN LAB_{it} + \beta_5 LN FDI_{it} + \beta_6 LN HCI_{it} + \varepsilon_{it} \quad (4)$$

where, LN denotes the natural logarithm of the variable. The coefficients β_1 , β_2 , β_3 , β_4 , β_5 and β_6 are the long-run elasticities of economic growth in terms of per capita energy use, per capita trade, per capita capital, labour, per capita foreign direct investment and human capital index.

3.2. Data

All annual data over the period of 1980–2018 for this study, except human capital index, were obtained from the World Development Indicators (WDI, 2020), World Bank database. The data used are of the

world's 20 biggest economies, namely Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Netherlands, Russian Federation, Saudi Arabia, Spain, Switzerland, Turkey, United Kingdom and the United States. The data on energy use for the years 2015, 2016, 2017 and 2018 were collected from BP (2019) Statistical Review. The human capital index data were sourced from Feenstra et al. (2015).

3.3. Econometric approach

This study follows several econometric techniques. First, this study uses a cross-sectional dependence test to carry out the shock effect. Second, Pesaran's (2007) cross-sectionally augmented Dickey–Fuller (CADF) panel unit root test is used to test the stationary of the variables. Third, the equilibrium relationship is assessed using the cointegration tests of Pedroni (1999, 2004) and Kao (1999). Fourth, the long and short term equilibrium associations are tested by using the panel pooled mean group estimator. Finally, the direction of causality is explored using the heterogeneous panel causality test of Dumitrescu and Hurlin (2012).

3.3.1. Cross-sectional dependence

Cross-sectional dependence among the variables may decide the selection of economic analysis used in this study. The cross-sectional dependence across countries arises due to the presence of similar economic, financial and political shocks. Therefore, it is better to check the presence of cross-sectional dependence prior to the detection of unit roots among the variables. We use four different cross-sectional dependence tests, namely Breusch and Pagan (1980) BP LM test, Pesaran (2004) scaled LM test, Pesaran (2004) CD test, Baltagi et al. (2012) biased-corrected scaled LM test as follows:

Breusch and Pagan (1980) introduce the following panel data model for examining cross-sectional dependence.

$$CD_{BP} = \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}^2 \tag{5}$$

Pesaran (2004) develops the following LM statistics to overcome to the disadvantages of Breusch and Pagan (1980) test.

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (\hat{\rho}_{ij}^2 - 1) \tag{6}$$

Pesaran (2004) recommends that if the cross-sectional size is larger than the time dimension, the following test statistic can be used instead.

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}^2 \tag{7}$$

Baltagi et al. (2012) develop the scaled LM test statistics by using a simple asymptotic bias correction as follows:

$$CD_{BC} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (\hat{\rho}_{ij}^2 - 1) - \frac{N}{2(T-1)} \tag{8}$$

Where $\hat{\rho}_{ij}$ indicates a correlation between the errors. The null hypothesis of this test is H0: no cross-sectional dependence. The alternative hypothesis of this test is H1: cross-sectional dependence.

3.3.2. Panel unit root test

Pesaran (2007) develops the CADF panel unit root test that accounts for cross-sectional dependence in panel data. The CADF unit root test can be measured using the following equation:

$$\Delta x_{it} = \alpha_i + p_1 x_{it-1} + c_1 \bar{x}_{t-1} + \sum_{j=0}^n d_{ij} \Delta \bar{x}_{it-1} + \sum_{j=0}^k \beta_{ij} \Delta x_{it-1} + \varepsilon_{it} \tag{9}$$

Where, \bar{x}_{t-1} and $\Delta \bar{x}_{it-1}$ are correspondingly the cross-sectional averages of lagged levels and first differences individual series.

3.3.3. Co-integration test

A residual based cointegration test as proposed by Pedroni (1999, 2004), has two types: panel tests and group tests. In the panel test, the within dimension approach entails four statistics i.e. panel v, panel rho, panel PP and panel ADF, while in the group test, the between dimension approach encompasses three statistics e.g. group rho, group PP and group ADF. All of the statistics are standard, normal and asymptotically distributed relying on the assessed residuals emanated from the underlying long-run model:

$$Y_{it} = \alpha_i + \lambda_i + \sum_{j=1}^m \beta_{ji} X_{jit} + \varepsilon_{it} \tag{10}$$

Where, in levels X and Y are presumed to be integrated at order one.

The construction of the estimated residuals is as under:

$$\varepsilon_{it} = p_i \varepsilon_{it-1} + u_{it} \tag{11}$$

In this study, the comparison will be made based on maximum likelihood panel cointegration statistics considering four within-dimensions and three between-dimensions, where the null hypothesis mandates that there is no co-integration among the studied variables. According to the methodology of Pedroni (1999, 2004) the cointegration system for panel data is as under:

$$Y_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it} \tag{12}$$

Another co-integration test recommended by Kao (1999) estimates the homogeneous co-integration relationship by using two tests: the Dickey-Fuller type and the Augmented Dicky Fuller type, considering the null of no co-integration.

3.3.4. Pool mean group panel ARDL estimate

We adopted a pool mean group (PMG) panel autoregressive distributed lag (ARDL) approach since this study investigates the dynamic of economic growth, energy use, trade, capital, labour, foreign direct investment and human capital index.

$$\Delta(Y_i)_t = \sum_{j=1}^{p-1} \gamma_j^i \Delta(Y_i)_{t-1} + \sum_{j=1}^{q-1} \delta_j^i \Delta(X_i)_{t-1} + \varnothing^i [(Y_i)_{t-1} - \{\beta_0^i + \beta_0^i (X_i)_{t-1}\}] + \varepsilon_{it} \tag{13}$$

Where, Y indicates the economic growth. X represents a set of independent variables that consist of energy use, trade, capital, labour, foreign direct investment and human capital index. γ and δ represent the short-term coefficients of dependent and independent variables respectively. The long-term coefficients are represented by β . \varnothing denotes the coefficient of the speed of adjustment to a long-term relationship. ε is a time-varying error term. The subscripts of i and t indicate country and time. The term within square brackets indicates the long-term growth regression. Using the above equation, the panel ARDL method of PMG estimator will be used.

3.3.5. Heterogeneous panel causality test

Dumitrescu and Hurlin (2012) developed the heterogeneous panel causality test to examine the short-term bivariate causal relationship between the variables. Since this study's cross-section dimension consists of a 39 years time span for 20 countries, this test is useful because the cross-section dimension is present and time (T) is larger than panel (N). This test is made on the assumption that all the coefficients will be unlike across cross-sections. In this test two separate distributions are prevalent such as the asymptotic and the semi-asymptotic, where the asymptotic distribution is applied when T is larger than N and the semi-asymptotic distribution is employed when N is larger than T.

The following model is used to check the existence of causality in panel data:

$$y_{it} = \alpha_i + \sum_{j=1}^J \lambda_i^j y_{it-j} + \sum_{j=1}^J \beta_i^j x_{it-j} + \varepsilon_{it} \tag{14}$$

Where $x_{i,t}$ and $y_{i,t}$ are represented as the observations of two stationary variables for the individual i in period t, j portrays the lag length, $\lambda_i^{(j)}$

shows the autoregressive parameter, and $\beta_i^{(j)}$ represents the regression coefficient which varies within the groups. In this study we assumed the identical lag order J for all individuals the panel is balanced. This test generates a fixed coefficient model, which is normally distributed and permits for heterogeneity.

It assumes the null hypothesis of no causal association and the alternative hypothesis is for causal relationship between variables, which are given below:

$$H_0: \beta_i = 0 \forall i = 1, \dots, N$$

$$H_1: \beta_i \neq 0 \forall i = 1, \dots, N_i$$

$$\beta_i \neq 0 \forall i = N_1 + 1, N_1 + 2, \dots, N$$

Here, N_1 denotes the unknown parameter that satisfies the condition $0 \leq N_1/N < 1$. The ratio of N_1/N should be inferior to 1, because $N_1 = N$ implies no causal relationship of the cross-section in the panel, where we fail to reject the null hypothesis but $N_1 = 0$ indicates a causal association for all individuals in the panel.

4. Results and discussions

4.1. Descriptive statistics

The descriptive statistics of the studied variables are delineated in Table 2. The average natural logarithmic form GDP per capita is 9.68 and its minimum and maximum values are 5.85 and 11.28, respectively. The mean of the natural logarithms of energy use, trade, capital, labour, foreign direct investment and human capital index are 7.88, 8.92, 8.29, 17.41, 5.13 and 1.01, respectively. The Jarque-Bera test rejects the hypothesis of normality when the p-value is less than or equal to 0.05. Failing the normality test allows to state, with 95% confidence, the data does not fit the normal distribution. The natural logarithmic values of GDP per capita, energy use, trade, capital, foreign direct investment and

human capital index denote negatively skewed whereas the labour shows positively skewed. Similarly, the natural logarithmic values of labour shows mesokurtic, but GDP per capita, capital, and foreign direct investment indicate leptokurtic whereas the energy use and human capital index determine platykurtic.

4.2. Cross-sectional dependence test results

Table 3 displays the results from four different cross-sectional dependence test values and their corresponding probability values.

The probability values for all cross-sectional dependence values of all variables in this study are significant at 1% level and rejecting the null hypothesis of cross-sectional independence indicating that there is sufficient cross-sectional dependency among variables across all countries in different panels. Under this condition, the use of standard econometric estimation may provide spurious results. Therefore, we use dynamic model of the PMG panel ARDL estimation approach that accounts for cross-sectional heterogeneity through the short-term parameters and facilitates both long-run and short-run causalities inferences. ARDL model can be used regardless of whether the series is 1(1) or 1(0).

4.3. Unit root test results

We use the cross-sectional ADF unit root test (CADF) proposed by Pesaran (2007), which takes into account the cross-sectional dependence issue. Table 4 presents the results with and without the trend of panel unit root test. In case of without trend, all the variables are non-stationary at the level but they, except LNHCI, are stationary at first difference. However, in case of constant and trend, all the variables including LNHCI become stationary at their first differences. Pesaran et al. (2001) recommend that the ARDL can be accommodated whether the series is stationary I(1) or non-stationary I(0) or mutually cointegrated variables in the same regression.

Table 2. Descriptive statistics.

	LNGDP	LNENG	LNTRA	LNCAP	LNLAB	LNFDI	LNHCI
Mean	9.680	7.878	8.915	8.290	17.412	5.134	1.005
Median	10.205	8.158	9.323	8.659	17.180	5.431	1.067
Maximum	11.275	9.147	11.508	9.889	20.484	10.712	1.324
Minimum	5.850	5.657	3.764	4.380	15.154	-4.423	0.251
Std. Dev.	1.233	0.822	1.500	1.104	1.273	2.081	0.254
Skewness	-1.210	-0.805	-1.047	-1.376	0.543	-0.800	-0.751
Kurtosis	3.732	2.765	4.130	4.878	3.015	4.434	2.593
Jarque-Bera	207.655	85.963	184.064	360.839	38.309	150.121	78.658
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	780	780	780	780	780	780	780

Note: All the variables are transformed into the natural logarithm form. The Jarque-Bera test is used to see whether a series is normally distributed or not. The null hypothesis of this test is a series is normally distributed.

Table 3. Cross-sectional dependence test results.

Variables	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
LNGDP	5351.382*** (0.000)	264.773*** (0.000)	264.510*** (0.000)	66.206*** (0.000)
LNENG	3057.362*** (0.000)	147.093*** (0.000)	146.829*** (0.000)	24.488*** (0.000)
LNTRA	5221.507*** (0.000)	258.111*** (0.000)	257.848*** (0.000)	66.828*** (0.000)
LNCAP	2814.773*** (0.000)	134.648*** (0.000)	134.385*** (0.000)	34.430*** (0.000)
LNLAB	5553.235*** (0.000)	275.128*** (0.000)	274.865*** (0.000)	69.878*** (0.000)
LNFDI	2976.667*** (0.000)	142.953*** (0.000)	142.690*** (0.000)	50.169*** (0.000)
LNHCI	6938.897*** (0.000)	346.211*** (0.000)	345.948*** (0.000)	83.144*** (0.000)

Note: *** denotes 1% significance level. Figures in the parentheses are probabilities.

Table 4. Unit root test results.

Variables	Constant		Constant and trend	
	Level	1 st difference	Level	1 st difference
LNGDP	-1.782	-2.289***	-1.964	-3.430***
LNENG	-1.657	-2.532***	-1.977	-2.995***
LNTRA	-1.969	-2.480***	-2.388	-3.333***
LNCAP	-1.567	-2.452***	-2.448	-3.005***
LNLAB	-2.188	-2.797***	-2.541	-3.588***
LNFDI	-1.672	-3.497***	-2.311	-3.636***
LNHCI	-1.913	-1.763	-2.343	-3.431***

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

Table 5. Pedroni and Kao panel cointegration test results.

Pedroni cointegration test				
Estimates	Statistic	Prob.	Weighted Statistics	Prob.
<i>Alternative hypothesis: common AR coefficients (within-dimension)</i>				
Panel v-Statistic	2.234**	0.013	1.648**	0.050
Panel rho-Statistic	3.249	0.999	2.557	0.995
Panel PP-Statistic	-0.279	0.390	-1.073	0.142
Panel ADF-Statistic	-0.398	0.345	-2.058**	0.020
	Statistic		Prob.	
<i>Alternative hypothesis: individual AR coefficients (between-dimension)</i>				
Group rho-Statistic	4.103		1.000	
Group PP-Statistic	-0.070		0.472	
Group ADF-Statistic	-2.080**		0.019	
Kao cointegration test				
Statistic		t-statistic		Prob.
ADF		-2.843***		0.002

Note: *** and ** denote significance level at 1%, and 5%, respectively.

4.4. Cointegration test results

This study uses two types of panel cointegration tests suggested by Pedroni (1999, 2004) and Kao (1999) to see the existence of the long-run link between economic growth, energy use, trade, capital, labour, foreign direct investment and human capital index. The results (Table 5) imply that there is a long-term link between variables. Both panel cointegration tests reject the null hypothesis; therefore, this study can continue with an estimation of the parameters of the dynamic error-correction model using the PMG method.

4.5. PMG estimation results

Table 6 reports the PMG estimation of the long-term and short-term coefficients. With regard to the long-term relationship, all independent variables used in this study, namely energy use, trade, capital, labour, foreign direct investment and human capital index have a positive and significant effect on economic growth. A one percent increase in energy use, trade, capital, labour, foreign direct investment and human capital index increases economic growth by 0.23%, 0.13%, 0.33%, 0.20%, 0.01% and 1.81%, respectively. ECT term is negative and significant, confirming the long run cointegration among the variables.

The energy use increases the economic growth, implying that energy facilitates more production by facilitating the use of different energy led machinery and equipment in the long run. This result is consistent as energy is considered as an important factor of production. This outcome is in line of findings of Saidi et al. (2017), Rahman et al. (2019) and Azam (2020) but contradictory to the findings of Lee and Chang (2007) and Wolde-Rufael (2009). The positive result of trade is also consistent and relevant as

Table 6. PMG estimation results.

Variable	Coefficient	Std. Error	T-Statistic	Prob.
Long Run				
LNENG	0.228	0.037	6.164	0.000
LNTRA	0.133	0.023	5.683	0.000
LNCAP	0.327	0.022	14.678	0.000
LNLAB	0.200	0.063	3.196	0.002
LNFDI	0.008	0.003	2.423	0.016
LNHCI	1.807	0.220	8.231	0.000
ECT	-0.167	0.032	-5.233	0.000
Short Run				
ΔLNENG	0.065	0.024	2.737	0.006
ΔLNTRA	0.049	0.026	1.874	0.061
ΔLNCAP	0.116	0.021	5.605	0.000
ΔLNLAB	-0.004	0.075	-0.049	0.961
ΔLNFDI	0.000	0.001	0.231	0.817
ΔLNHCI	-0.621	0.179	-3.467	0.001
Constant	-0.188	0.064	-2.932	0.004

countries can obtain favourable balance of payments through earnings of more foreign exchange from exports. Also, trade increases the export capacities via the imports of raw materials and capital goods that eventually lead economic growth. This finding is pertinent with Were (2015), Busse and Koeniger (2015), Pradhan et al. (2017) and Keho (2017) but is not pertinent with Musila and Yiheyis (2015), Ali and Abdullah (2015), Kurihara and Fukushima (2016), and Moyo and Khobai (2018). Accordingly, labour and capital also provide their traditional role on fostering the economic growth. In the same way, foreign direct investment and human capital provide positive impetus on the economic growth. The FDI creates huge investment to augment the economic activities and facilitate the development process in an erudite way. This finding is supported by Rahman and Salahuddin (2010), Shahbaz and Rahman (2010), Omri and Kahouli (2014), and Azam and Ahmed (2015) but is not supported by Belloumi and Alshehry (2018), and Bakari and Tiba (2019). Similarly, human capital development expands economic growth, as skilled manpower contributes more efficiently in promoting the development activities. Our result is similar to the findings of Pelinescu (2015), Azam and Ahmed (2015), Alataş and Çakır (2016), Fashina et al. (2018) and Diebolt and Hippe (2019) but does not support the finding of Abubakar et al. (2015).

In the short run, (Table 6) the coefficients of energy use, trade and capital are positively linked with economic growth; in contrast, the human capital is negatively linked with economic growth, implying that the benefit from human capital development on economic growth is not immediate but is observed in the long run. This is rational and consistent. The energy-driven effect is greater than the trade-driven effect on the economic growth of these countries in both the short and long runs.

4.6. Country specific short-term test results

Table 7 compares the country-specific results with general findings in the short-term. Energy use positively affects economic growth in the short-run in Australia, Brazil, Canada, Italy, Japan, Korea, Mexico, Russia, Saudi Arabia, Spain, Turkey and the USA, whereas energy use reduces economic growth in the short-run in China, France, Germany, Netherlands, Switzerland and the UK. Trade increases economic growth in Australia, Canada, France, Germany, Italy, Japan, Korea, Mexico, Netherland, Saudi Arabia, Spain, Switzerland and Turkey. In contrast, trade negatively influences economic growth in Brazil, Russia, the UK and the USA.

4.7. Results of Dumitrescu and Hurlin (2012) panel causality test

The results of panel causality tests based on Dumitrescu and Hurlin (2012) are displayed in Table 8. There is a one-way causality running

Table 7. Short-term country specific results on all sample countries.

Country	ECT	LNENG	LNTRA	LNCAP	LNLAB	LNFDI	LNHCI	Constant
Australia	-0.165***	0.062***	0.051***	0.115***	-0.293***	-0.001***	0.069***	-0.160
Brazil	-0.056***	0.322***	-0.006***	0.245***	0.071***	-0.003***	0.073*	-0.010*
Canada	-0.211***	0.042***	0.087***	0.084***	0.102	0.000***	-2.695	-0.213**
China	-0.273***	-0.138***	0.000	0.138***	0.003	0.009***	-0.296*	-0.688**
France	-0.137***	-0.021***	0.046***	0.149***	0.057*	0.000***	-0.638***	-0.106**
Germany	-0.103***	-0.022***	0.100***	0.156***	-0.074*	-0.002***	-0.667	-0.131***
India	0.002	-0.020**	-0.020***	0.132***	0.094**	-0.006***	0.144	0.021***
Indonesia	0.013***	0.129***	-0.047***	-0.020***	-0.312**	0.005***	-1.143	0.090***
Italy	-0.004*	0.076***	0.059***	0.199***	0.023**	-0.001***	-0.480*	0.023***
Japan	-0.131***	0.157***	0.005***	0.244***	-0.024	0.000***	-1.746**	-0.136**
Korea, Rep.	-0.085***	0.082***	0.017***	0.213***	0.114**	0.000***	-0.636**	-0.076
Mexico	-0.145***	0.026*	0.003**	0.165***	-0.095**	0.003***	-0.540	-0.108**
Netherlands	-0.393***	-0.003**	0.060***	0.014***	0.068**	-0.001***	-0.394	-0.343
Russian Federation	-0.519***	0.233**	-0.066***	0.000	1.108**	-0.002***	-0.458	-1.173*
Saudi Arabia	-0.144***	0.048**	0.486***	-0.123***	-0.584	0.000***	0.813	-0.039
Spain	-0.125***	0.085***	0.027***	0.180***	-0.293***	-0.002***	-0.571**	-0.052*
Switzerland	-0.057***	-0.011**	0.175***	0.072***	-0.401***	0.000***	0.319	-0.035**
Turkey	-0.378***	0.046***	0.042***	0.102***	0.075**	0.004***	-0.700***	-0.133***
United Kingdom	-0.317***	-0.013***	-0.026***	0.108***	0.293**	-0.001***	-1.832**	-0.341
United States	-0.109***	0.227***	-0.014***	0.147***	-0.008	0.002***	-1.043	-0.156***

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

from economic growth to energy use confirming the conservation hypothesis and foreign direct investment. This study also confirms the bidirectional causal relationship between economic growth and trade, capital, labour and human capital development.

4.8. Robustness check

The long-term findings from the panel ARDL method of PMG estimator are checked using two alternative single equation estimators of the Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS).

Table 9 shows the results of the panel FMOLS and DOLS estimations. The obtained results for most of the variables, except labour and human capital index, are in line with the findings of the PMG estimation. Energy, trade, capital and FDI have positive significant effects on economic growth. The findings of human capital index are inconclusive, showing positive and negative effects in DOLS and FMOLS estimations, respectively. The positive effect of this variable is consistent with the findings of PMG estimation.

Table 8. Causality test results.

Null Hypothesis:	W-Stat.	Prob.	Decision
LNENG does not cause LNGDP	1.691	0.386	LNGDP → LNENG
LNGDP does not cause LNENG	5.249***	0.000	(unidirectional causality)
LNTRA does not cause LNGDP	4.027***	0.000	LNTRA ↔ LNGDP
LNGDP does not cause LNTRA	4.447***	0.000	(bidirectional causality)
LNCAP does not cause LNGDP	4.056***	0.000	LNCAP ↔ LNGDP
LNGDP does not cause LNCAP	4.056***	0.000	(bidirectional causality)
LNLAB does not cause LNGDP	7.257***	0.000	LNLAB ↔ LNGDP
LNGDP does not cause LNLAB	6.975***	0.000	(bidirectional causality)
LNFDI does not cause LNGDP	2.516	0.453	LNGDP → LNFDI
LNGDP does not cause LNFDI	7.750***	0.000	(unidirectional causality)
LNHCI does not cause LNGDP	6.539***	0.000	LNHCI ↔ LNGDP
LNGDP does not cause LNHCI	3.979***	0.000	(bidirectional causality)

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

5. Conclusion and policy implications

This work attempts to probe the drivers of economic growth in a panel of the world's 20 biggest economies by utilizing data of 39 years (1980–2018). The panel autoregressive distributed lag (ARDL) method of Pool Mean Group (PMG) estimator and heterogeneous panel causality test are being applied as estimation strategies with due consideration of cross sectional dependence test, cointegration test and other necessary diagnostic tests. The obtained results endorse the cointegration among the variables used, and energy use, trade, capital, labour, foreign direct investment and human capital development have positive and significant impacts on the economic growth of these countries in the long run. Furthermore, energy use, trade and capital also have positive and significant effect but human capital has negative effects on economic growth in the short run. A bidirectional causality between economic growth and trade, capital, labour and human capital, and unidirectional causality from economic growth to energy use and foreign direct investment are also found. The attained results are theoretically consistent and have important policy implications for the world which will be a new avenue to create certain and lucid policy initiatives. The policy implication from our results is: continuous and sustained economic growth is to be ensured by formulating suitable and appropriate trade policy, energy policy, human capital development policy and FDI policy and undertaking the required reforms and actions. Specifically, the following recommendations should get attention:

Table 9. The results of panel FMOLS and DOLS estimation.

Method	Panel FMOLS	Panel DOLS
LNENG	0.435*** (0.045)	0.359*** (0.068)
LNTRA	0.091*** (0.024)	0.401*** (0.032)
LNCAP	0.129*** (0.016)	0.083*** (0.030)
LNLAB	0.126 (0.081)	-0.339 (0.079)
LNFDI	0.010** (0.004)	0.002*** (0.009)
LNHCI	-0.775*** (0.225)	0.374** (0.157)

Note: *** and ** indicate significance level at 1% and 5%, respectively. Figures in the parentheses show standard error.

- i. *Appropriate trade policy reforms*: Trade barriers and disputes among the trade partners must be reduced. The prolonged trade tension may create the poor economic growth in the panel countries and in the world which is undesirable. In this regard, the world trade organization (WTO) may take the necessary steps to lessen the trade related disputes between and among the states in the context of bilateral and multilateral trade policies.
- ii. *Sustainable energy policy reforms*: It is essential to formulate sustainable energy policy to get the long term fruit of energy on economic growth by suitable and sustainable energy mix (clean energy, renewable energy and non-renewable energy) considering environmental and health benefits across the globe. The concerted efforts are essential to ensure energy efficiency by providing widespread access to clean and renewable energy and becoming less dependent on non-renewable and fossil fuel based energy for securing economic growth. A well-coordinated strategy among the panel countries focusing on policy regulations, policy enforcement and policy management of the energy sector is required. The smart design, effective implementation and transparent monitoring of the sustainable energy policy mix can be a pioneering to foster long-run economic growth without compromising the environmental quality.
- iii. *Suitable human capital development policy reforms*: Human capital must be enriched by more investment in health and education sectors to make people more productive. Although the returns from the investments on human capital may not be achieved in the economy in the short-run due to the longer implementation time of the young students to join in the workforce, the benefits of such investments are visible in the long run. For this reason, the countries should adopt modern education, skill development activities, training, massive investment on science and technology, and ensure adequate health facilities for their people in order to reap the full potential of available workforce.
- iv. *Growth friendly FDI policy reforms*: Since FDI significantly affects economic growth, a cooperative and concerted effort of the global leaders is needed to attract more FDI in the sample countries by emphasizing FDI oriented strategies like establishing an export processing zone, exclusive and special economic zone, favorable fiscal reforms, and trade liberalization, and allowing more facilities for export oriented investments. The foreign investors must enjoy the full investment facilities in different countries. In this regard conducive, comprehensive and well-planned growth oriented FDI policy reforms are essential to achieve and maintain the much needed economic growth.

Like every study, this study has also some limitations. For example, we could not include some factors such as technological improvement, social and political factors, institutional frameworks, infrastructure, and law and orders, etc. which might have influence on economic growth as well. Future research can be directed to include these variables for better insight.

Declarations

Author contribution statement

Mohammad Mafizur Rahman: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Khosrul Alam: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data associated with this study has been deposited to this journal as an appendix under supplementary file: (1) Except human capital index, all the data is collected from the World Development Indicators (WDI, 2020), World Bank database (Sources: WDI (2020). World Development Indicators. World Bank data base. Washington, D.C., <https://data.worldbank.org/>). (2) The data on energy use for the years 2015, 2016, 2017 and 2018 were collected from BP (2019) Statistical Review (Source: BP (2019). BP Statistical Review 2019. <https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>). (3) The human capital index data were sourced from Feenstra et al. (2015) (Source: Feenstra et al. (2015)); =<https://www.aeaweb.org/articles?id=10.1257/aer.20130954>.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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