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Article

Measuring Energy Poverty and Its Impact on Economic Growth in Pakistan

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Abstract: During the last two decades, energy poverty has captured a growing attention of researchers and policymakers due to its strong association with economic poverty and poor economic performance. This study uses a broad set of macro level indicators and makes the first attempt to measure energy poverty and its impact on economic growth of Pakistan over the period 1990 to 2017. In particular, our energy poverty indicator considers four main dimensions of energy poverty, namely, energy services, clean energy, energy governance and energy affordability. Our main results show that though the overall energy poverty has reduced in Pakistan during the selected sample period, the country shows an increasing dependence on polluted energy supply in order to meet its growing demand of energy. In second stage of the investigation, we test the neoclassical growth theory where we incorporate energy poverty along with human capital as source of economic growth. Our cointegration results reveal a strong relationship between energy poverty and economic growth that is also dynamically stable in short run. These strong negative linkages between energy poverty with economic growth for the sample economy complement the previous literature on the subject.

Keywords: energy poverty; economic growth; energy governance; multidimensional poverty

JEL Classification: O11; O13; O44; Q43; Q48

1. Introduction

According to Prof. Nurkse, a country is poor due to its poor performance on demand and supply sides [1]. Further this poor performance pushes the society into vicious circle of poverty. Limited or low access to economic opportunities is sign of economic poverty and vice versa. On the same token, energy poverty is a situation where a household doesn't meet materially and socially established level of energy [2]. Likewise, at aggregate level, unavailability of modern and cheap sources of energy are considered as hurdle for efficient productivity which strengthen the vicious circle of poverty [3]. In present era, energy sector is facing two global issues, namely, energy security and global warming. Both these issues are directly and indirectly linked with energy poverty which further causes economic poverty [4]. Therefore, an energy poor nation is unlikely to fight with the other social and economic evils due to its inability to use modern and affordable energy for economic activities [5]. Poor nations, despite spending a large portion of their limited income on expensive and dirty energy, get (and provide) sub-optimal energy services. In this sense, the problem of poverty remains closely intertwined with a lack of cleaner and affordable energy services.

Despite the key importance of the subject, precise measurement of energy poverty turns out to be an unsolved puzzle in the empirical literature. The main problem is that we cannot measure energy poverty with a single proxy variable since it would partially represent this menace. Indeed, as argued by Atkinson and Bourguignon [6], measurement

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of energy poverty is a tough job and the factors like economic, infrastructural and social development, and, the ones related to the overall environmental quality can easily influence this indicator [7]. Therefore, designing an energy poverty index that covers all these aspects becomes an important tool to address the modern global agenda. A comprehensive and multi-dimensional energy poverty index can also be used to bring together heterogeneous aspects of energy poverty and to see their impact on economic poverty. All this can certainly help us in formulating polices in order to break the vicious circles of poverty.

The modern global energy agenda simultaneously focuses on the alleviation of economic and energy poverties. Every country tries to provide universal access to clean and affordable energy by 2030 according to Sustainable Development Goals (SDGs 2015; for more details, visit https://www.undp.org/sustainable-development-goals). To bring modern solutions to these issues, the question related to the precise measurement of energy poverty remains important for the policymakers and researchers working in this field [4,8].

Coming to our sample economy, energy crisis (or energy poverty) is the largest drain of the economy of Pakistan that hurts the GDP by two to four percent annually [9]. The availability of energy is quite low in the country. For instance, in 2017, it is hardly near 500 kg of ton of oil equivalent (TOE) as compared to developed countries where per capita energy consumption is on average 6000 kg of TOE per capita. Pakistan economy experienced various issues that determine the status of its energy poverty over time. These include fiscal issues (i.e., circular debt, subsidies, and import bill), energy governance related issues (i.e., transmission and distribution losses, effective energy pricing and institutional backwardness or lack of transparency), and environmental aspects (i.e., a heavy reliance on dirty energy sources despite the vast potential of green energy in the country). It is also worth mentioning that our sample economy is going through the transitional phases of growth path where energy intensity increases with the process of economic development. Similarly, the factors like rapid population growth and expansion of industrial and transport sectors are also causing higher more energy demand over time and widening the energy gap in Pakistan [10].

2. Energy Poverty: Some Measurement Issues

Measurement of energy poverty remains an unresolved issue in empirical energy–development literature. To this end, the seminal contribution came from Boardman [11] who gives the concept of (fuel) energy poverty and tries to measure it for the UK economy after the oil price shocks of 1970s. However, the study takes only two aspects of energy poverty, namely, energy availability and energy affordability. In the subsequent literature, a bulk of studies tries to measure energy poverty using various indicators and sample economies [3,7,12,13]. These studies can mainly be divided into three categories. In the first category, energy poverty is simply measured by the share of income or expenditure of household going to energy consumption. If a household is unable to spend a threshold level of income on energy then it is considered to be energy poor [14,15]. Schuessler [16] called it "The Ten Percent Rule". Nevertheless, this approach contains some serious measurement issues since it is widely held in the literature that households mostly over-report their income share on energy consumption and under-report their exact income. The second approach draws a threshold level of energy via engineering (technology) based estimations [17]. This method of obtaining the threshold level of energy poverty is highly technical and it is revised overtime. One important drawback of this method is that it focuses only on absolute energy poverty and thus does not incorporate the relative energy poverty. An appropriate energy poverty index should be a combination of both socio-economic and technological factors rather than income share and conventional engineering considerations. The third approach is concord with the construction of multidimensional or comprehensive index to analyze energy poverty [18,19]. This approach is comprehensive since it incorporates several socio-economic and technological aspects of energy poverty. Secondly, this method also presents the evolution of energy situation over-time. Finally, for the policymaking purposes, we can further dig each dimension of energy poverty to set the goals.

In present study, we follow the last approach and construct a multidimensional index for energy poverty for Pakistan by using time series data from 1990 to 2017. Our selection of the starting year is based on the availability of data for several indicators of energy poverty. The reliability and authenticity of the data is foundational stone for any empirical investigation. In this study, we use various authentic sources of secondary data for the construction of energy poverty index in Pakistan. Table 1 reports the data sources of all the indicators of energy poverty index. We categorize the index into four dimensions: energy services availability, clean energy, energy governance and energy affordability. Further, these four dimensions are based on seventeen proxy indicators of the equal weight. Following sections elaborate the rationale behind using each indicator of the selected categories of the index.

2.1. Energy Services Availability

Availability of energy at affordable prices is a real challenge for developing countries. These countries not only have to meet their growing energy needs but also need to enhance their renewable energy capacity in order to meet the Sustainable Development Goals (SDGs 2015) of UNDP [3]. Taking the case of Pakistan economy, Shahbaz [20] shows that the unavailability of energy has held back the annual GDP growth rate of the country by at least two percent during the period 1991 to 2013. The previous literature shows a strong relationship between energy poverty and provision of energy services. Availability of energy services is used as a proxy variable to measure energy poverty in Europe [21]. The International Energy Agency (IEA) described energy poverty as "a lack of access to modern energy services…." (see http://www.iea.org/topics/energypoverty/). Wang et al. [19] also associate energy poverty with the availability and quality of energy services. Following these developments, we use energy services availability as the first dimension of our energy poverty index.

For the construction of this dimension, we employed five indicators with equal weights as representatives of energy services availability. Four indicators are taken from supply side and one composite indicator, total energy use, from the demand side. Our first indicator covers energy services dimension and is based on rural population's access to electricity [19]. In Pakistan, distribution of electricity is totally managed by the public sector. According to WDI estimates, 63.56% of the country's population is still living in rural areas (for more details, visit https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=PK). However, in 2017, around 97% of the rural population has access to electricity which is substantial improvement over 1990 when only 45% of the rural population was electrified. Our remaining three supply side variables include domestic crude oil production, total energy supply by all potential sources and access to electricity as percentage of urban population. A higher rate of domestic oil production lowers the dependence on imported energy and hence reduces energy-poverty.

2.2. Clean Energy

It is widely held in the energy–growth literature that higher economic growth usually comes at the cost of rapid environmental degradation. The tradeoff between output growth and environmental quality is explained by the fact that more production needs more energy consumption and hence more emissions of hazardous gases. For the developing economies like Pakistan, this implies that a reduction of energy poverty may lead to a rapid degradation of the environmental quality. However, energy poverty elimination without compromising the environmental quality can be achieved if the share of clean energy in the total energy mix increases over-time. This takes us to the second dimension of our energy poverty index which is clean energy. It mainly focuses on assessing the cost of energy poverty elimination in the form of environment degradation [4]. To this end,

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the previous literature shows that sustainability of environment is direct linked with quality of energy services [19].

In the construction of clean energy index, we mainly rely upon six indicators. These indicators contain data regarding countries' reliance on renewable (clean) and non-renewable (dirty) energy uses. On the clean energy side, indicators like alternative and nuclear energy [23], access to clean fuels and technologies for cooking, and, share of renewable energy (hydro production) explain a country's preferences for clean energy over-time [24]. On the other hand, indicators such as share of non-renewable energy, bio-fuels and waste and, overall CO_2 emissions explain trends in dirty energy across different time periods [25]. Our particular focus on the clean energy is also motivated by the fact that after the 21st conference on climate, held in Paris (COP21), global community is more and more emphasizing on the environmental quality and reducing the reliance on dirty energy sources like coal and fossil fuels (https://ec.europa.eu/clima/policies/international/negotiations/paris_en). Nevertheless, in Pakistan the scenario is completely different since the country has recently received a heavy inflow of FDI in energy sector under the umbrella of China-Pakistan Economic Corridor (CPEC). However, the energy production from these CPEC related projects is mainly based on coal power plants containing the potential for more CO_2 emissions.

2.3. Energy Governance

In developing countries, a main root cause of energy poverty is the existence of poor governance structure. In case of Pakistan, the main governance problems include compromised pricing-policies, high transmission and distribution losses, switching from low-cost to high-cost energy generation projects, and limited capacity addition over the past many years. These factors play a significant role in determining the magnitude of energy poverty and energy insecurity [26]. Energy governance is mainly concerned with the provision of energy services at optimal cost and time [27[. Mainly, there are two aspects of energy governance. The first one is the institutional management while the second one corresponds to a combination of financial governance and management related governance which is basically linked with procurement and distribution sides of energy. Among all these elements, factors like institutional and financial governance can be considered as exogenous since they capture the overall governance situation in Pakistan. In this case, the issue of energy governance is mainly related to the procurement and distribution of electricity [27]. To capture the energy governance, we therefore rely upon the transmission and distribution losses of the country. According to World Bank statistics, total distribution and line losses of Japan are nearly 4.4% of total electricity while, in Pakistan, they amount to nearly 17.5% of the total electricity generation. In the fiscal year 2007-08 about 7.6 percent of total tax collection was spent on the provision of energy subsidies. The same spending reaches to around 18 percent of total tax collection in the fiscal year 2011-12 [28]. The growing share of subsidy of energy sector shows a poor governance structure of the country. In the present study, we use three indicators (having equal weights) as proxies of energy related governance. The first two indicators are linked with the domestic supply side governance while the last indicator shows the country's dependence on the imported energy. On this last indicator, the higher the country's dependence on imported energy, the higher will be the magnitude of any supply side shock on the domestic GDP growth [26]. In this study, we are just focusing on national level energy governance. While, Van de Graaf and Colgan [29] discuss the global level energy governance issues.

2.4. Energy Affordability

The issue related to energy affordability is often considered as a vague concept [30]. However, many others argued that the concept of affordability has sound theoretical justifications [31]. According to theory, energy affordability implies a situation where a consumer or household can afford energy within the limits of his/her budget. In this context, energy affordability is mainly the problem of low-income households or low income nations at global level [7]. There exists an inverse relationship between energy affordability and energy poverty. Therefore, cost effective energy efficiency can reduce energy poverty

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[32]. Wang et al. [19] and Bollino and Botti [21] discussed energy affordability as a dimension of energy poverty. In the literature, there are mainly two approaches to measure the energy affordability: expenditure approach and consensual-based approach [21]. The first approach is micro-based method where we measure the share of household income spent on energy items. The second approach is more macro-based and here we assess the energy affordability with some aggregate level proxy variables. In this study, we calculate affordability using the second approach in order to keep this variable consistent with the remaining data set. To capture the energy affordability, we take three proxy variables. The first variable is total four-wheel registration or motorization and the second is two-wheel registration. The motorization rate is number of passenger cars per 1,000 inhabitants. Motorization rate is widely used as an indicator to compare the level of economic development across countries. While two-wheel motorization is used as proxy for energy affordability of low-income and lower-middle income classes of society, a high rate of motorization shows high level of energy affordability. For instance, in Pakistan, the motorization rate is only 17 while in European Union (EU) it is 581 (see https://www.statista.com/statistics/610820/motorization-rate-in-selected-countries/). Besides, we also use total registered gas consumers as a proxy indicator of energy affordability. Being a developing nation, our sample economy is continuously moving from biofuel to natural gas consumption. Hence a shift towards more natural gas consumption would reflect an increase in energy affordability over-time.

Table 1. Multidimensional energy poverty index.

	Dimensions	Indicators	Hypothesis	Data Source
Energy Poverty Index	*Energy Services*	Access to electricity, rural (% of rural population)	+	WDI*
		Domestic crude oil production (TOE)	+	IEA**
		Total energy supply by all sources in KTOE	+	IEA
		Access to electricity (% of urban population)	+	WDI
		Energy use (kg of oil equivalent)	+	WDI
	Clean Energy	Alternative and nuclear energy (% of total energy use)	+	PEB***
		CO_2 emissions (metric tons per capita)	-	WDI
		Access to clean fuels and technologies for cooking (% of population)	+	WDI
		Share of renewable energy (hydro production)	+	IEA
		Share of non-renewable (coal consumption KTOE)	-	IEA
		Biofuels and waste KTOE	-	IEA
	Energy Governance	Transmission and distribution losses (electricity billion kwh)	-	PEB
		Generation billion KW	+	IEA
		Energy imports, net (% of energy use)	-	WDI
	Energy Affordability	Number of consumers of gas	+	PEB
		Registered four wheels out of 1000 people	+	PBS****
		Registered two wheels for 1000 people	+	PBS

Notes: *World Development Indicators of World Bank, **International Energy Agency, ***Pakistan Energy Year Book (various editions), ****Pakistan Bauru of Statistics.

3. Methodology

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As our index of energy poverty exploits 17 types of indicators with different scales, directions and properties, our first task is to descale these indicators in order to make a homogenous index of energy poverty. For this purpose, we employ following two formulae based on cost and benefit [19,22].

$$Benifit: \quad X_t^i \quad = \frac{Max x_t^i - x_t^i}{Max\, x_t^i - Min x_t^i},$$

$$Cost: \quad X_t^i \quad = \frac{x_t^i - Min\ {}_t^i}{Max\, x_t^i - Min x_t^i},$$

where capital X_t^i is normalized value and x_t^i is actual value of x variable at year t, and 'i' represents the indicators (i.e., $i = 1, 2, \cdots, 17$). The modified variable X_t^i is both dimension and scale free and its value lies between zero and one. Our next task is to award the weight to each indicator. There are diverse views regarding the allocation of weights depending upon the ultimate objective of energy poverty measurement [21,23]. In the present study, we give equal weight to each dimension (i.e., 0.25) in order to avoid biasedness. We argue that an increase in these indicators would contribute equally to economic growth and welfare. For example, our first dimension, energy services, comprises five indicators, each having same weight of 0.2. Rest of the three dimensions have four indicators each having weight of 0.25.

The details of the four dimensions and their respective indicators are shown in Table 2. We then move to testing the correlation of Energy Poverty Index (EPI) with respect to its dimensions. This is done in the last column of Table 2. As shown by the results, the correlation coefficient between energy services and EPI is 0.92, implying a very strong positive association between energy services and energy poverty. But the linear association between clean energy and energy governance indicators with the EPI is in moderate zone. Finally, our fourth dimension, energy affordability exhibits the strongest correlation with EPI and the value of correlation coefficient amounts to 0.95 in this case.

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Table 2. Weight distributions and correlation results between index and dimensions.

	Dimensions	Indicators	Correlation (Dimension, EPI)
Energy Poverty Index	*1/4(Energy Services)*	1/5(Access to electricity, rural (% of rural population))	0.92578
		1/5(Domestic crude oil production (TOE))	
		1/5(Total energy supply by all sources in KTOE)	
		1/5(Access to electricity (% of urban population))	
		1/5(Energy use (kg of oil equivalent))	
	1/4(Clean Energy)	1/6(Alternative and nuclear energy (% of total energy use))	0.60597
		1/6(CO_2 emissions (metric tons per capita))	
		1/6(Access to clean fuels and technologies for cooking (% of population))	
		1/6(Share of non-renewable (coal))	
		1/6(Share of renewable energy (hydro production))	
		1/6(Biofuels and waste KTOE)	
	1/4(Energy Governance)	1/3(Transmission and distribution losses (electricity billion kwh))	0.460029
		1/3(Generation billion KW)	
		1/3(Energy imports, net (% of energy use))	
	1/4(Energy Affordability)	1/3(Number of consumers of gas)	0.95205
		1/3(Registered four wheels out of 1,000 people)	
		1/3(Registered two wheels for 1,000 people)	

4. Energy Poverty

In the present analysis, we rely upon the following equation in order to calculate the EPI:

$$(EPI)_t = ¼\{(Energy\ Services)_t + (Energy\ Governance)_t + (Clean\ Energy)_t + (Energy\ Affordability)_t\}.$$

The value of the index lies between zero and one. A low value indicates reduction in energy-poverty and vice-versa. The evolution of energy poverty index over time is shown by Figure 1. As shown by the negatively sloped line, Pakistan economy observed improvements on the energy poverty fronts over the entire sample period. Nevertheless, the speed of reduction is slow and experiences upward movements at several occasions. If we divide this whole period into three-decade wise sub-periods, we can link the energy poverty with the political instability in Pakistan. In the first decade comprising the period 1990–1999, the country experienced political instability due to the fact that four democratic governments were ousted from office before the completion of their constitutional tenure. As a result of this political instability, all the macroeconomic indicators including energy poverty alleviation observed downward trend. The situation stabilized temporarily in 1999 when the military dictator Pervaiz Musharraf assumed the office of chief executive. During the period 1999 to 2007, the country experienced an overall political stability although the law-and-order condition started deteriorating from 2006 onwards due to terrorists' activities. This diverted the resources from economic development to defense and hence the energy poverty increased again. At the same time, oil prices at global level tripled

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within 18-months that cause 36% increase in import bill and increase the intensity of energy poverty [9]. The next important event is 2008 general elections and the transition of regime from dictatorship to democracy. Following this successful transition, the country is experiencing an improvement in energy poverty alleviation, nonetheless, the speed is relatively slow due to both external (i.e., international financial crisis and episodes of oil price hikes) and internal (i.e., weak economic growth of Pakistan, terrorism and increasing public debt) factors. The latest increase in EPI over the period 2016–2017 can mainly be linked with the domestic factors.

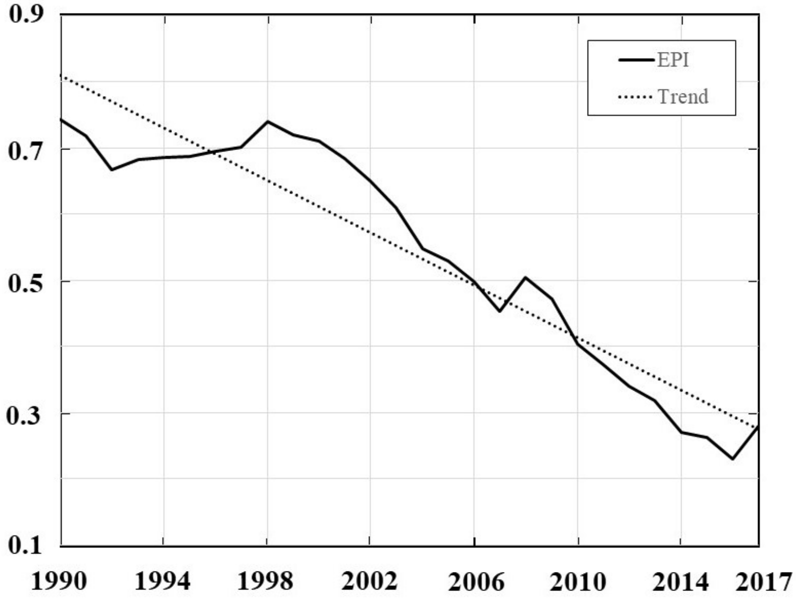

Figure 1, Evolution of energy poverty index over-time.

4.1. Energy Services and Energy Poverty

Energy services at affordable prices are considered as source of economic growth, productivity, and welfare. The provision of energy services also determines energy intensity or energy conservation. Efficient energy services availability at affordable prices are considered important for poverty reduction since they involve both operating costs and investment [33]. In order to analyze the relationship between energy poverty and energy services, Figure 2 plots these two variables over the selected sample period. Here again, the decade of 90s observed weak performance in the provision of energy services due to the factors detailed above. The outcome of this underinvestment was a continuous increase in energy poverty during the first decade. The comparison of dotted and thick lines also shows that during the 1990s, energy services did not contribute to energy poverty reduction. The trend reversed from 2000 onwards, illustrating a strong correlation between energy poverty and energy services. Therefore, the role of energy services in energy poverty reduction increased in the last two decades.

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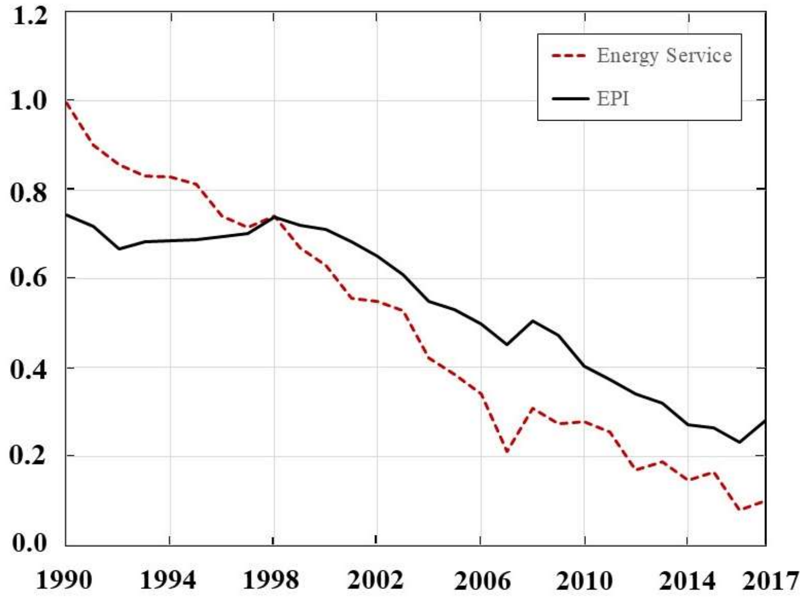

Figure 2. Energy services and energy poverty.

4.2. Clean Energy and Energy Poverty

Although the provision of cheap and uninterrupted energy supply is a pre-condition for long-run growth of modern economies, the recent decades observed a particular attention to the provision of clean energy. Figure 3 summarizes the relationship between clean energy and energy poverty in case of Pakistan. The graph shows a very volatile behavior of clean energy indicator over-time. On the whole, the share of clean energy in the total energy mix remained satisfactory till 2008. However, starting from 2008, Pakistan economy entered into an era of chronic energy crisis that forced the successive governments to opt for short term solutions including the energy production from national and international independent power producers (IPPs), working on the imported oil. The real cost of such policies in the form of climate change is continuously increasing at compounding rate. The recent trend in this degradation came after the start of CPEC related energy projects that mainly rely on imported coal for the provision of electricity. The increasing trend of the clean energy indicator also presents an alarming situation for the sustainable development of Pakistan economy.

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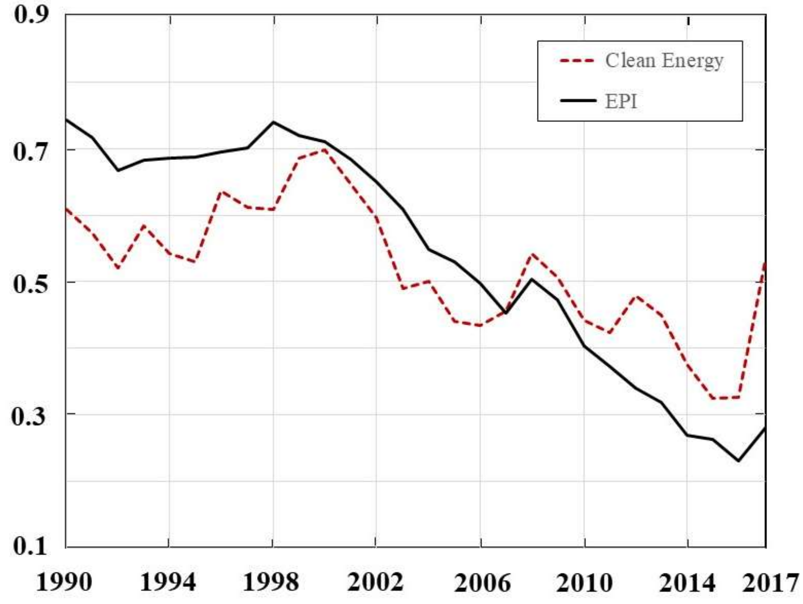

Figure 3. Clean energy and energy poverty.

4.3. Energy Governance and Energy Poverty

Our next task is to discuss the governance performance of energy sector of Pakistan and its relationship with our proposed EPI. The energy governance implies the overall performance of all those institutions that are considered as movers and shakers of energy in Pakistan. The situation of energy governance is not substantially different from the overall governance condition of our selected economy [22]. Figure 4 shows the overall condition of governance indicator during the selected sample period and its correlation with EPI. Consistent with the previous indicators, energy governance shows fluctuations over-time. The correlation between energy governance and EPI is strongest in the middle decade of the sample period compared to the first and third decades, again explaining the positive role of political stability on the energy governance and hence energy poverty reduction.

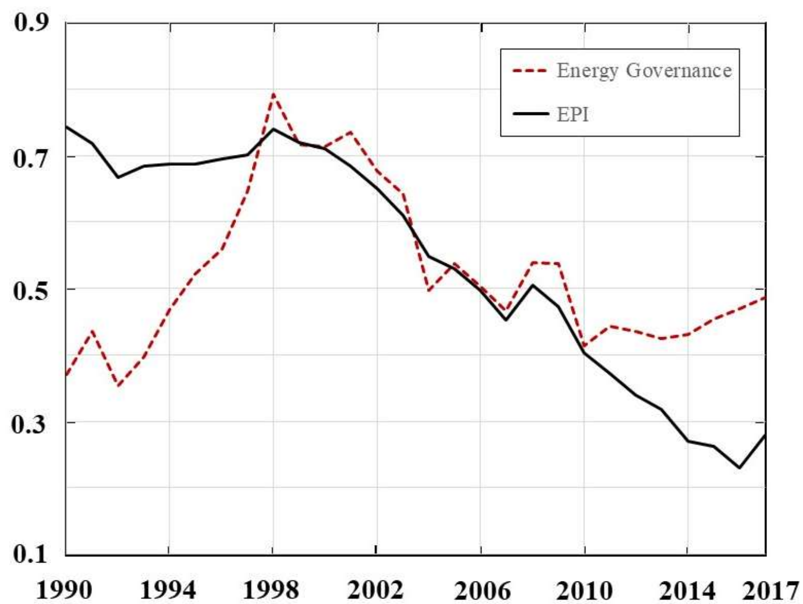

Figure 4. Energy governance and energy poverty.

4.4. Energy Affordability and Energy Poverty

Our last dimension of EPI, energy affordability, calculated by our proposed method, is depicted in Figure 5. This indicator shows an encouraging trend for Pakistan since energy affordability of the society continues to increase during the selected time period. This can be due to an increasing demand for wheels in the economy coming from factors like changes in preferences, better road conditions, improved living standards and fast population growth. Furthermore, the country is also experiencing the process of rapid urbanization, implying more demand for vehicles.

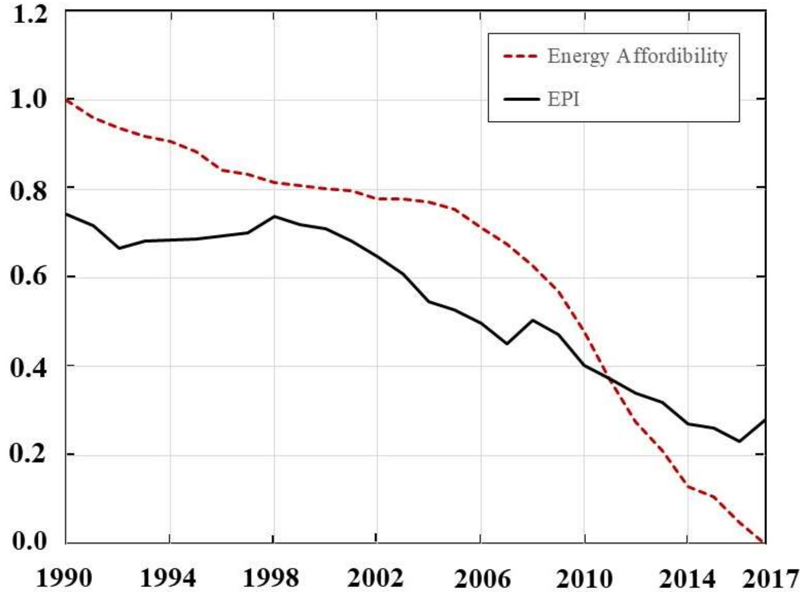

Figure 5. Energy affordability and energy poverty.

5. Energy Poverty and Economic Growth

For our econometric analysis, we use the proposed energy poverty index in order to test its impact of economic growth of the sample economy. Starting from the seminal work by Solow [34], the growth literature has persistently highlighted the contribution of labor and capital for economic growth. The recent developments in this literature acknowledge the relevance of various economic, social, technological, and demographic factors for countries' economic development [35]. Based on these developments, the following Cobb-Douglas production function type econometric model is proposed to analyze the significance of energy poverty along with the other neoclassical factors on economic growth of Pakistan:

$$Y_t = e^{\alpha_0} {EP_t}^{\alpha_1} {HC_t}^{\alpha_2} {K_t}^{\alpha_3} e^{u_t}, \quad (1)$$

where Y shows economic growth, EP presents energy poverty, HC is for human capital, and K captures the investment rates. Since the above model is non-linear with respect to variables, we conduct the following a logarithmic transformation in order to make it log-linear:

$$lnY_t = \alpha_0 + \alpha_1 lnEP_t + \alpha_2 lnHC_t + \alpha_3 lnK_t + u_t. \quad (2)$$

One of the advantages of using a double-log model is that it provides the elasticities in form of estimated parameters. For instance, in the above case, the elasticity of economic growth with respect to energy poverty can be expressed in the following way;

 doi:10.20944/preprints202108.0314.v1

$$\varepsilon_{Y,EP} = \alpha_1$$

The hypothesized sign of α_1 should be negative in the present study, illustrating the fact that a reduction in energy poverty accelerates economic growth. For the estimation of equation (2), we use total gross value added as a proxy of our dependent variable, economic growth [36]. For the independent variables, we use the data of average years of schooling as an indicator of human capital whereas physical capital accumulation has been proxied by gross fixed capital formation. Data of these three variables are collected from the World Development Indicators (WDI) of World Bank [37].

For the estimation of this multivariate energy poverty and economic development model, our empirical strategy comprises four steps investigation where, in the first step, we test the stationarity properties of the selected variable; in the second step, we conduct cointegration tests; in the third step, we retrieve short-run and long run estimates of the variable and, in the final step, we present the variance decomposition matrices of economic development and energy poverty variables.

5.1. Stationarity Tests

In order to test the unit root properties of the data series, we rely upon two different stationarity tests including ADF (augmented Dickey-Fuller) test [38] and PP test [39]. The results of these tests are presented in Table 3. As can be viewed from the tests results, all the variables are non-stationary at level and stationary at first difference. In $I(1)$ case with a single cointegrating vector, one simply regresses one of the variables onto contemporaneous levels of the remaining variables, leads and lags of their first differences, and a constant, using either ordinary or generalized least squares. The resulting "dynamic OLS" (respectively GLS) estimators are asymptotically equivalent to the Johansen/Ahn-Reinsel estimator [40].

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Table 3. ADF and PP test of unit root.

Variable	Augmented Dickey-Fuller (ADF) Test				Phillips Perron (PP) Test				Remarks
	Intercept		Intercept with trend		Intercept		Intercept with trend		
	Level	1st Diff.	Level	1st Diff.	Level	1st Diff.	Level	1st Diff.	
LY	-0.11	-3.56**	-2.88	-3.46**	-0.32	-3.56***	-2.14	-3.47**	$I(1)$
LHC	-1.1	-4.98*	-0.99	-5.14*	-1.15	-4.98*	-1.02	-5.16*	$I(1)$
LEP	0.19	-5.05*	-1.73	-5.15*	0.21	-5.07*	-1.72	-5.14*	$I(1)$
LK	-0.26	-4.31*	-1.80	-4.23**	-0.31	-4.29*	-1.96	-4.21**	$I(1)$

Notes: a) The critical values of unit root test (ADF and PP) are -4.33, -3.58, and -3.22 (with trend) and -3.69, -2.97, and -2.62 (without trend), respectively, at 1%, 5%, and 10% significance levels. b) *, **, and *** denote significance at 1%, 5% and 10% levels, respectively.

5.2. Johansen Cointegration Test

After establishing the stationarity of the selected variables at $I(1)$, we conduct cointegration analysis using Johansen cointegration technique in order to test the long-run relationship among the selected variables. The calculated statistics for both trace and maximum eigen values are presented in Table 4. These findings confirm the existence of long-run relationship between income, human capital, physical capital and energy poverty of the selected sample economy. These results are consistent with the findings of Amin et al. [41] who support the existence of cointegration relationship between energy poverty and economic development for South Asian economies.

Table 4. Result of cointegration test.

Unrestricted Cointegration Rank Test (Trace)					Unrestricted Cointegration Rank Test (Maximum Eigen Value)			
Hypothesized No. of CE(s)	Eigenvalue	Trace statistics	0.05 critical value	*p*-value	Eigenvalue	Max-eigen statistics	0.05 critical value	*p*-value
None	0.71	53.44	47.86	0.014*	0.70	32.93	27.58	0.009*
At Most 1	0.40	20.51	29.79	0.391	0.39	13.59	27.13	0.390
At Most 2	0.18	6.91	15.49	0.588	0.18	5.39	14.26	0.690
At Most 3	0.06	1.51	3.84	0.210	0.05	1.51	3.84	0.210

Note: * indicates significance at 5% level.

5.3. Long Run and Short Run Results

Once the cointegration is established, the next task is to get the long-run and short-run impact of human capital, physical capital and energy poverty on economic development of Pakistan economy. These outcomes are reported in Table 5. It is worth mentioning that the long run coefficients of the variables are normalized and hence the signs are reversed. For instance, the coefficient of energy poverty implies that a 1% increase in energy poverty will lead to 0.052% decrease in economic growth. Similarly, an increase in human and physical capital accumulation by 1 percent will lead to 0.876% and 0.132% increase in the long-run output growth. However, in the short run, economic growth is only explained by its own changes in the previous period. The coefficient of the error correction term is -0.37 showing that it takes around three years before deviation in the short-run values converge to the long-run equilibrium. These results are consistent with (Amin et al., 2020) who report growth inhibiting effect of energy poverty for their selected South Asian economies.

Table 5. Results of long run and short run analysis.

Dependent Variable: Income	Coefficient	*t*-test
Long term elasticities		
LEP	0.052***	2.683
LHC	-0.876***	-30.899
LK	-0.132***	-6.837
Short term elasticities		
ECT	-0.370*	-1.88
Δ(LY(-1))	0.558***	2.42
Δ (LEP)	-0.004	-0.08
Δ(LHC(-1))	-1.106	-0.48
Δ(LK(-1))	0.006	0.19
Diagnostic tests	Test statistic	*p*-value
Jarque-Bera normality (joint)	8.61	0.38
Breusch-Godfrey LM test	14.77	0.54

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

5.4. Variance Decomposition Analysis

The last part of our empirical results comprises variance decomposition of both the variables of interest, namely economic growth and energy poverty. These results are shown in the Table 6. For both the variables of interest, the decomposition of shock to any variable stretches over the period of ten years. As depicted by the variance decomposition analysis, a shock to income accounts for whole variance of income in the first year. However, after ten years, the share of income goes down to nearly 82 percent while energy poverty becomes the second most important factor by explaining just over 8 percent variation in income. The share of human capital remains around 2.36 percent whereas physical capital accounts for 7.68 percent variation in income after 10 years. Similar pattern can be observed for energy poverty where in the first poverty almost 100 variations in this variable are explained by itself. However, after 10 years the effect of shock to energy poverty on the energy poverty goes down to 70.52 percent whereas income accounts for 25.89 percent changes in energy poverty. The share of human and physical capital accumulation in the variability of energy poverty is negligible even after 10 years. For both these variables, the respective share remains 2.43 percent and 0.17 percent for the variability of energy poverty in Pakistan.

Table 6. Results of variance decomposition.

(a) Variance Decomposition of GDP					
Period	**S.E.**	**LY**	**LEP**	**LHC**	**LK**
1	0.02	100.00	0.00	0.00	0.00
2	0.03	96.24	0.96	0.55	2.26
3	0.04	89.30	3.92	1.51	5.27
4	0.04	85.06	6.19	2.02	6.74
5	0.05	83.61	7.08	2.17	7.14
6	0.05	83.24	7.33	2.20	7.23
7	0.06	82.94	7.49	2.24	7.33
8	0.06	82.56	7.69	2.28	7.47
9	0.06	82.20	7.88	2.33	7.59
10	0.07	81.94	8.02	2.36	7.68
(b) Variance Decomposition of LEP					
Period	**S.E.**	**LY**	**LEP**	**LHC**	**LGFC**
1	0.08	0.79	99.21	0.00	0.00
2	0.11	5.32	92.90	1.61	0.17
3	0.14	12.50	83.92	3.12	0.46
4	0.17	18.39	77.94	3.33	0.34
5	0.19	21.60	74.84	3.27	0.30
6	0.20	23.12	73.34	3.27	0.27
7	0.22	23.99	72.45	3.32	0.24
8	0.23	24.71	71.70	3.37	0.21
9	0.25	25.36	71.05	3.40	0.18
10	0.26	25.89	70.52	3.42	0.17

6. Conclusions

Energy is considered as lifeline for economies in the modern era. An economy working with subsistence level of energy will definitely be the one with subsistence level of economic development. Hence energy poverty becomes an economic issue and a growing level of energy poverty can lead to several social conflicts within the energy scarce societies. Likewise, dependence of polluted energy to solve the energy poverty problem can trigger environmental problems and threaten the sustainable development of the country. Keeping in view all these aspects of energy poverty, the issue attracted a lot of attention from researchers and international organizations working on the subject. Exact quantification of the energy poverty, nonetheless, remains a challenging task for both energy economists and policymakers. In the literature, there are mainly three approaches to quantify this concept. The first one is 'The Ten Percent Rule' (TTPR) by [11,16]; the second method relies upon drawing a threshold level of energy use with some engineering models [15], and, the third technique constructs a comprehensive index for energy poverty [19,42].

In the present study, we follow the last approach and calculate the energy poverty in case of Pakistan. To the best of our knowledge, our study is the first attempt to measure the energy poverty by utilizing time series data of Pakistan economy. We develop an index by classifying the energy poverty into four dimensions: energy services availability, clean energy, energy governance and energy affordability. Further these four dimensions are based on seventeen indicators with equal weights. After the construction of EPI, we investigate the relationship between energy poverty and economic development. Moreover, we also test the relationship between EPI and the overall economic fitness. Our main results can be summarized as follows: first, over the selected sample period, Pakistan economy has made substantial advancements on its journey from an energy-poor state to energy rich country. Second, the availability of energy services is also in its transitional phase due to intensive electrification over the sample period, as shown by the energy supply index. Third, improvement in EP is negatively linked with the provision of clean energy supply in case of Pakistan. This implies that although country's energy supply has seen improvements, it still faces serious threats on sustainable environmental quality fronts due to the fact that the share of dirty energy in the total energy mix is increasing rapidly. Fourth, poor energy governance is also a hurdle in solving the issue of energy poverty. Poor energy governance is mainly the outcome of overall political uncertainty in the last three decades. Fifth, we also find a strong negative correlation between energy poverty and economic development. Lastly, energy poverty is also firmly linked with economic fitness in case of Pakistan.

On the basis of all these results, the study concludes that energy poverty is serious threat for the sustainable development of Pakistan. Since it is energy availability at affordable price that can rescue Pakistan economy from the vicious circle of poverty, energy enrichment can be considered as modern 'big-push' for the country's economic development. In order to experience such big-push, the country, however, needs a well-designed assistance programme that can break the technological, social and economic bottle necks [13]. Lastly, our findings have sound implications for the improvements of energy governance and clean-energy for Pakistan and for the other developing countries in general. Without substantial improvements on these two fronts, developing countries can never reap the benefits of sustainable development by merely inviting FDI in their polluted energy production sectors.

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Abbreviations

COP21	21st conference on climate held in Paris
CPEC	China-Pakistan Economic Corridor
EPI	Energy Poverty Index
EU	European Union
FDI	Foreign Direct Investment
IEA	International Energy Agency
PBS	Pakistan Bauru of Statistics
PEB	Pakistan Energy Year Book
SDGs	Sustainable Development Goals
TOE	Ton of Oil Equivalent
UNDP	United Nations Development Programme
WDI	World Development Indicators

References

1. Bauer, P.T. The vicious circle of poverty. Weltwirtschaftliches Archiv **1965**, 95, 4–20. https://www.jstor.org/stable/pdf/40436342.pdf
2. Buzar, S. Energy Poverty in Eastern Europe: Hidden Geographies of Deprivation. Routledge, **2007**. https://www.routledge.com/Energy-Poverty-in-Eastern-Europe-Hidden-Geographies-of-Deprivation/Buzar/p/book/9780754671305
3. Karekezi, S.; McDade, S.; Boardman, B.; Kimani, J.; Lustig, N. Energy, poverty, and development. In Global Energy Assessment Writing Team, Global Energy Assessment: Toward a Sustainable Future, Cambridge: Cambridge University Press, **2012**, 151–190. https://doi.org/10.1017/CBO9780511793677.008
4. Chakravarty, S.; Tavoni, M. Energy poverty alleviation and climate change mitigation: Is there a trade off? Energy Economics **2013**, 40(S1), S67–S73. https://doi.org/10.1016/J.ENECO.2013.09.022
5. Dagoumas, A.; Kitsios, F. Assessing the impact of the economic crisis on energy poverty in Greece. Sustainable Cities and Society **2014**, 13, 267–278. https://doi.org/10.1016/j.scs.2014.02.004
6. Atkinson, A.B.; Bourguignon, F. The comparison of multi-dimensioned distributions of economic status. Review of Economic Studies **1982**, 49(2), 183–201. https://doi.org/10.2307/2297269
7. Pachauri, S.; Spreng, D. Measuring and monitoring energy poverty. Energy Policy **2011**, 39(12), 7497–7504. https://doi.org/10.1016/j.enpol.2011.07.008
8. International Energy Forum. Energy access and affordability. Paper presented at the 16th International Energy Forum Ministerial, April 10–12, **2018**, New Delhi, India. https://www.ief.org/_resources/files/events/ief16-ministerial/ief16-ofid-background-paper.pdf
9. Aftab, S. Pakistan's energy crisis: Causes, consequences and possible remedies. Expert Analysis, Norwegian Peacebuilding Resource Centre (NOREF), January **2014**, 1–6. https://www.files.ethz.ch/isn/177484/ade59fba5daf67a11a1c217434abf440.pdf
10. Javed, M.S.; Raza, R.; Hassan, I.; Saeed, R.; Shaheen, N.; Iqbal, J.; Shaukat, S.F. The energy crisis in Pakistan: A possible solution via biomass-based waste. Journal of Renewable and Sustainable Energy **2016**, 8(4), 043102. https://doi.org/10.1063/1.4959974
11. Boardman, B. Fuel Poverty : From Cold Homes to Affordable Warmth. London: Belhaven Press, **1991**. https://books.google.fr/books/about/Fuel_Poverty.html?id=HwYtAAAAMAAJ&redir_esc=y
12. Ketting, N.G. Towards a sustainable energy future. Energy Policy **1995**, 23(7), 637–638. https://doi.org/10.1016/0301-4215(95)98219-I
13. Sovacool, B.K. The political economy of energy poverty: A review of key challenges. Energy for Sustainable Development **2012**, 16(3), 272–282. https://doi.org/10.1016/j.esd.2012.05.006
14. Day, R.; Walker, G.; Simcock, N. Conceptualising energy use and energy poverty using a capabilities framework. Energy Policy **2016**, 93, 255–264. https://doi.org/10.1016/J.ENPOL.2016.03.019
15. Foster, V.; Tre, J.-P.; Wodon, Q. Energy prices, energy efficiency, and fuel poverty. Latin America and Caribbean Regional Studies Programme. Washington, DC: World Bank, **2000**. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.557.1335&rep=rep1&type=pdf
16. Schuessler, R. Energy poverty indicators: Conceptual issues - Part I: The ten-percent-rule and double median/mean indicators. ZEW-Centre for European Economic Research, Discussion Paper, No. 14-037, **2014**. https://doi.org/10.2139/ssrn.2459404
17. González-Eguino, M. Energy poverty: An overview. Renewable and Sustainable Energy Reviews **2015**, 47, 377–385. https://doi.org/10.1016/j.rser.2015.03.013
18. International Energy Agency. World Energy Outlook **2012**. https://webstore.iea.org/world-energy-outlook-2012-2
19. Wang, K.; Wang, Y.X.; Li, K.; Wei, Y.M. Energy poverty in China: An index based comprehensive evaluation. Renewable and Sustainable Energy Reviews **2015**, 47, 308–323. https://doi.org/10.1016/j.rser.2015.03.041
20. Shahbaz, M. Measuring economic cost of electricity shortage: Current challenges and future prospects in Pakistan. MPRA Paper 67164, **2015**.
21. Bollino, C.A.; Botti, F. Energy poverty in Europe: A multidimensional approach. PSL Quarterly Review **2017**, 70(283), 473–507. https://doi.org/10.13133/2037-3643_70.283_4
22. Khan, R.E.A.; Ullah, S. Measuring the governance in Pakistan: An introduction to KU Index. Acta Economica **2014**, 12(21), 23–41. http://store.ectap.ro/articole/1009.pdf
23. Okushima, S. Gauging energy poverty: A multidimensional approach. Energy **2017**, 137, 1159–1166. https://doi.org/10.1016/j.energy.2017.05.137
24. Thiam, D.R. Renewable energy, poverty alleviation and developing nations: Evidence from Senegal. Journal of Energy in Southern Africa **2011**, 22(3), 23–34. http://www.scielo.org.za/pdf/jesa/v22n3/04.pdf
25. Papageorgiou, C.; Saam, M.; Schulte, P. Substitution between clean and dirty energy inputs: A macroeconomic perspective. Review of Economics and Statistics **2017**, 99(2), 281–290. https://doi.org/10.1162/REST_a_00592
26. Zaman, R.; Brudermann, T. Energy governance in the context of energy service security: A qualitative assessment of the electricity system in Bangladesh. Applied Energy **2018**, 223, 443–456. https://doi.org/10.1016/j.apenergy.2018.04.081
27. Khalid, I.; Mukhtar, A. Energy crisis: An issue of good governance, a way forward. Journal of Political Studies **2016**, 23(1), 101–116. http://pu.edu.pk/images/journal/pols/pdf-files/7 - IRAM - ASIA_v23_1_16.pdf
28. Amjad, R.; Burki, S.J. (eds.). Pakistan: Moving the Economy Forward. Delhi, India: Cambridge University Press, **2015**.

29. Van de Graaf, T.; Colgan, J. Global energy governance: A review and research agenda. Palgrave Communications **2016**, 2(1), 1–12. https://doi.org/10.1057/palcomms.2015.47
30. Bradley, R. Comment—Defining health insurance affordability: Unobserved heterogeneity matters. Journal of Health Economics **2009**, 28(1), 255–264. https://doi.org/10.1016/J.JHEALECO.2008.12.009
31. Whitehead, C.M.E. From need to affordability: An analysis of UK housing objectives. Urban Studies **1991**, 28(6), 871–887. https://doi.org/10.1080/00420989120081101
32. Department of Energy & Climate Change. Annual Report on Fuel Poverty Statistics 2011. UK: A National Statistics Publication, **2011**. Retrieved August 8, 2021, from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48138/2181-annual-report-fuel-poverty-stats-2011.pdf
33. Pachauri, S.; Brew-Hammond, A.; Barnes, D.F.; Bouille, D.H.; Gitonga, S.; Modi, V.; Prasad, G.; Rath, A.; Zerriffi, H.; Dafrallah, T.; Heruela, C.; Kemausuor, F.; Kowsari, R.; Nagai, Y.; Rijal, K.; Takada, M.; Wamukonya, N.; Sathaye, J. Energy access for development. In Global Energy Assessment Writing Team, Global Energy Assessment: Toward a Sustainable Future, Cambridge: Cambridge University Press, **2012**, 1401–1458. https://doi.org/10.1017/CBO9780511793677.025
34. Solow, R.M.A contribution to the theory of economic growth. Quarterly Journal of Economics **1956**, 70(1), 65–94. https://doi.org/10.2307/1884513
35. Mankiw, N.G.; Romer, D.; Weil, D.N. A contribution to the empirics of economic growth. Quarterly Journal of Economics **1992**, 107(2), 407–437. https://doi.org/10.2307/2118477
36. Khan, M.Z.; Khan, F.N. Estimating the demand for rail freight transport in Pakistan: A time series analysis. Journal of Rail Transport Planning and Management **2020**, 14, 100176. https://doi.org/10.1016/j.jrtpm.2019.100176
37. World Bank. World Development Indicators (WDI). Data Catalog, **2019**. https://datacatalog.worldbank.org/dataset/world-development-indicators
38. Dickey, D.A.; Fuller, W.A. Distribution of the estimators for autoregressive time series with a unit root. Journal of American Statistical Association **1979**, 74(366), 427–431. https://doi.org/10.2307/2286348
39. Phillips, P.C.B.; Perron, P. Testing for a unit root in time series regression. Biometrika **1988**, 75(2), 335–346. https://doi.org/10.1093/biomet/75.2.335
40. Stock, J.H.; Watson, M.W. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica **1993**, 61(4), 783–820. https://doi.org/10.2307/2951763
41. Amin, A.; Liu, Y.; Yu, J.; Chandio, A.A.; Rasool, S.F.; Luo, J.; Zaman, S. How does energy poverty affect economic development? A panel data analysis of South Asian countries. Environmental Science and Pollution Research **2020**, 27(25), 31623–31635. https://doi.org/10.1007/s11356-020-09173-6
42. Nussbaumer, P.; Bazilian, M.; Modi, V. Measuring energy poverty: Focusing on what matters. Renewable and Sustainable Energy Reviews **2012**, 16(1), 231–243. https://doi.org/10.1016/j.rser.2011.07.150