Defining of the energy poverty of the state through the analysis of Belt and Road influence on its alleviation in the context of sustainable development

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Abstract. Energy poverty is an issue, which is new to the scientific field and often omitted from the research. The contemporary approaches to it are various, still the major of them points that energy poverty exists in case the national energy sector and the economy in general lack the possibilities to provide sufficient, safe, reliable, and affordable energy to the consumers. This paper examines the energy sector of Pakistan to prove or refute the idea of energy poverty existence in the country. In addition to that the energy poverty in Pakistan, in case it exists needs to be defined, its reasons are to be examined and the possible solutions for its alleviation provided. The paper proves the mentioned idea with the help of the approach from the side of international infrastructure construction. The proposed approach includes the examination of the role of BRI in energy poverty alleviation in Pakistan. While the Initiative has a significant impact on the economy of the country, its energy sector isn't directly affected by BRI. The major results of the study encompass the following: the energy poverty measurement through index method is developed, based on demand for energy and its supply and imports' changes; the energy poverty in Pakistan persists and can't be alleviated by the international institutions; the effects of economic growth aren't automatically distributed in the economy, especially in the energy sector of the country and have limited effects on energy poverty.

1 Introduction

Energy poverty is often omitted from the poverty reviews, despite its obvious nature. The most common reference to energy poverty is the lack of possibilities to provide sufficient,

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safe, reliable, and affordable energy to the consumers in the country [1]. The most developed economies and the research on energy poverty in these add to these characteristics of energy poverty the issue of clean energy, hence, the country or a region can be poor in energy in case it can't afford production of clean energy. As a result, the major gap in the current research field lies in the sphere of defining energy poverty. The issue of energy poverty is highly topicable and has serious prospects of scientific development.

This paper aims at defining energy poverty in terms of developing economies on the example of Pakistan. The major steps for the achievement of the goal, taken in the research include:

- The research of causes of energy poverty and its extent, according to the provided methodology.
- Projection of energy poverty in the country considering the influence of international investments in infrastructure.
- The formulation of propositions for Pakistan to ease the effects of energy poverty.

The major results, acquired in this paper include the proof of the existence of energy poverty in Pakistan, the proof of the high influence of BRI on the country economy, with the absence of the direct influence on the energy sector. The overall recommendations for alleviation of the energy poverty include the basic steps, which are to be performed with respect to the lack of data and reliable forecasts on the future of the several regions of the country.

2 Materials and methods

The methodology of the article is based on the concept of energy poverty as a lack of energy with the described hereabove characteristics. For Pakistan the first step is to assess the energy balance of the country, after that it's necessary to compare energy generation and energy imports, in case the significant share of energy is imported, it can be concluded, that the country faces energy deficit. Due to the absence of data on energy prices for Pakistan, the major test on the existence of energy poverty is the weighted by energy production/imports elasticity of population with access to energy-by-energy generation (1).

$$E = \frac{\Delta P * EP}{\Delta G * EI} \tag{1}$$

Where ΔP is the year-to-year change of population with access to electricity, and ΔG is the change in total energy generation in the country, EI – energy imports share in energy mix, EP – energy production in the country share on energy mix.

The next step of the analysis lies in the field of the construction of the regression, based on exogenous variables, depicting the causes of energy poverty in the country and the role of energy sector in the GDP growth. The data for Pakistan is limited to the 2020 for energy generation. The Chou coefficient allows to test whether the angle coefficient of the regression lines vary before and after some date, in other words to test whether Belt and Road Initiative as the major contributor to the infrastructure development in the country has any influence on energy poverty in the country, while technological factor is a part of regression analysis. The second part of the regression analysis tests by the same methodology the influence of BRI on energy sector, just as the relevance of the causality of energy poverty, provided in the first part of the article.

Based on the acquired results of regression analysis, the propositions for the energy sector of Pakistan are made in accordance with the factors, which are significant in the regression equation.

3 Results

The energy sector of Pakistan can be characterized by the dominance of the conventional energy sources with high influence of oil and coal on energy generation due to their cheapness [2]. The high poverty rate in the country (25.8% of population, living under 2.15$ per day) and the high rate of private sector without access to electricity (approximately 40% of households) [3]. As the major consumers of electricity in the country with a high growth rate are the households, the industrial demand is comparatively low, nearly equal to the demand in the services sector. This characteristic makes the country energy industry highly sensitive to the energy price and lowers the influence of the ecological factor due to the necessity to fulfil the basic needs of population in energy.

When speaking of the energy mix, Pakistan is the net-importer of energy resources, despite the fact, that the country has some oil reserves [3]. As it can be seen from figure 1, the share of biofuels and waste in the energy mix is very high, just as the share of oil in energy generation.

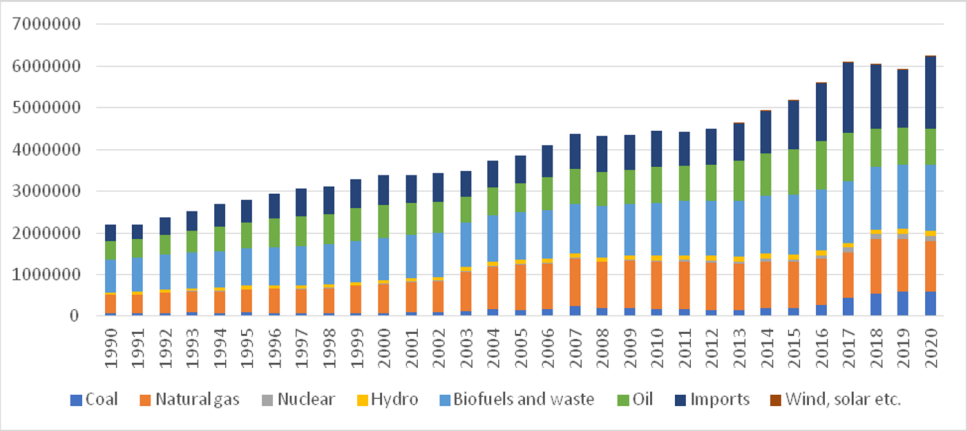

Fig. 1. Energy mix, including net energy imports in Pakistan, TJ. Source: developed by authors, based on IEA data [3].

The most important trend in the energy generation of Pakistan, pointing that the energy poverty in the country exists, is the growth of generation of energy from coal, cheap waste energy and oil. These are the cheapest energy sources in case the waste energy generation is dismantled to the basic energy sources. In Pakistan the generalized biofuels and waste category includes majorly biofuels from biowaste [4]. This source of energy is cheapest and may include heat generation from straw, debris etc., and surely is low-technological and non-reliable [5].

The other important observation is that the share of energy generation from coal is growing, just as the share of conventional energy generation on a faster pace, than the green energy generation, pinpointing the high influence of the internal factors on energy generation, such as the necessity to supply industrial regions, the need to provide basic energy services for population at least in the major cities etc. This can be concluded from the fact, that international institutions provide financial resources in compliment with their mandates, which state the priority of green projects in energy, while financial resources

from other countries and investment projects majorly concentrate in the spheres with higher ROI [6], today green energy has a higher ROI in short term, so in the situation of global turbulence is more attractive. Hence, the energy industry trends despite the desperate search of Pakistan for FDI are created from inside the country.

Figure 2 is a major proof of this idea, as the energy intensity of the industry in Pakistan is falling, while the GDP tends to grow. Simultaneously, the fall in energy elasticity by population in the recent years depicts the technological and economic crisis of the country economy, hitting hard on energy sector.

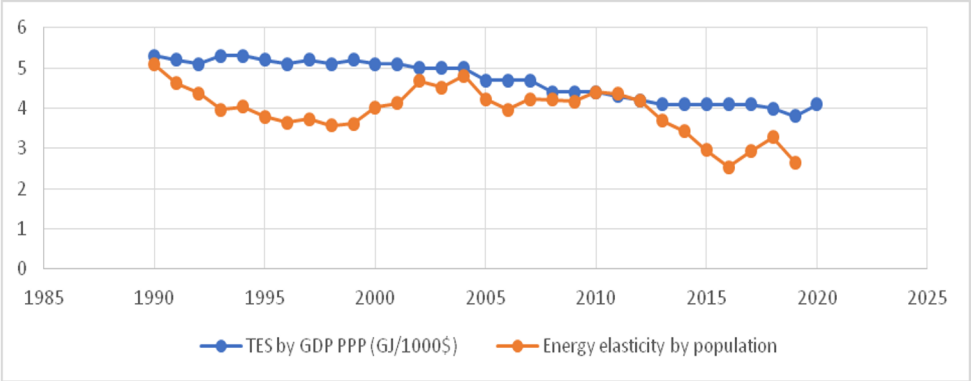

Fig. 2. Energy intensity indicators (total energy supply by GDP in PPP, GJ/US$1000; and energy elasticity by population). Source: developed by authors, based on IEA data [3].

It's notable, that this data demonstrates the higher pace of the development of the Pakistan GDP, than energy sector, not the better energy-presuming technologies or higher share of technologies, aimed at decreasing energy consumption, as the technological development of the country hasn't changed significantly, or at least is far from the required level for stable GDP growth [7].

To test this conclusion, it's necessary to conduct a regression analysis, considering the necessity to introduce Chow coefficient in 2013 to assess the BRI influence on the industry. The exogenous variables include the common list for testing the influence of energy industry on GDP, namely: FDI; generation of energy from a) coal, b) natural gas, c) oil, d) nuclear energy, e) hydroenergy, f) biofuels and waste, g) other renewable sources of energy (in Pakistan they are represented from 2012); foreign trade; population; share of urban population; inflation; technological development (in our case – technological readiness index) [3], [8]. The best fit of the model is acquired in the configuration, depicted in Table 1.

The data from table 1 clearly proves several important facts of energy industry and poverty in Pakistan. First and foremost, BRI has an impact on Pakistan GDP and energy sector in turn, but the impact on the latter is less important while the major influence is provided for the GDP of the country (this derives from the other test – the adequate model of the energy supply in Pakistan with exogenous variables population, urban population, FDI and technological readiness index has a p-value for Chou-test 0.25, which proves the H0).

The most economically influential energy sector is oil industry, while imports of energy play a vital role too. Simultaneously, the private sector (population, urban population share) plays a vital role in the energy sector supply through the influence of the demand of the sector.

FDI and technological development have a significant influence on Pakistan energy sector too, hence the BRI influence on the energy sector of Pakistan is majorly transited through these channels.

Table 1. The fit of the models with the conducted Chou-test for Pakistan, GDP and energy production.

GDP, 2000-2020 (T = 21), HAC, 2, Barlett				
	coefficient	**Std.error**	**t-ratio**	**p-value**
const	−8.48861e+06	1.82642e+06	−4.648	0.0056
Oil	0.213140	0.0363484	5.864	0.0020
Imports	−0.173987	0.0482350	−3.607	0.0154
TESbyGDP	53995.7	14798.5	3.649	0.0148
Foreign trade	4.87218	0.993407	4.905	0.0045
Population	−13.5413	3.07867	−4.398	0.0070
Share of urban population	313619	68936.2	4.549	0.0061
Technological readiness	−170209	27584.9	−6.170	0.0016
Split dummy	4.16960e+08	1.82642e+06	228.3	3.06e-11
Sd_oil	–0.481544	0.0363484	−13.25	4.38e-05
Sd_Imports	1.44890	0.0482350	30.04	7.67e-07
Sd_TESbyGDP	−3.17365e+06	14798.5	−214.5	4.18e-11
Sd_foreign trade	−117.487	0.993407	−118.3	8.20e-10
Sd_population	1272.18	3.07867	413.2	1.58e-12
Sd_share of urban population	−1.85875e+07	68936.2	−269.6	1.33e-11
Sd_Technological readiness	−5.82000e+06	27584.9	−211.0	4.54e-11
Mean dep. var.	198124.2	S.D. dep.var.	90619.39	Chow-test:
Sum. sqr. residuals	2.11e+08	S.K. of regression	6503.041	F (8,5)=5.4150e+08
R-squared	0.998713	Adjusted R-squared	0.994850	p-value=0.0000
Log-likelihood	−199.1099	Akaike criterion	430.2197	
Schwatz criterion	446.9321	Hannan-Quinn	433.8467	
rho	−0.490406	Durbin-Watson stat [9].	2.979779	
Energy production, 2000-2020 (T = 21)				
	coefficient	Std.error	t-ratio	p-value
const	−3.21552e+07	4.45604e+06	−7.216	<0.0001
PKPopU	1.30598e+06	192769	6.775	<0.0001
PKFDI	62.9605	10.1327	6.214	<0.0001
PKPop	−50.5567	11.5311	−4.384	0.0005
PKI	−1.40823e+06	479090	−2.939	0.0096
Mean dep. var.	3609410	S.D. dep.var.	604492.0	Chow-test:
Sum. sqr. residuals	5.06e+10	S.K. of regression	56219.58	F(5,11)>1.53234
R-squared	0.993080	Adjusted R-squared	0.991350	p-value=0.257549
Log-likelihood	−256.6198	Akaike criterion	523.2397	
Schwatz criterion	528.4623	Hannan-Quinn	524.3731	
rho	0.278266	Durbin-Watson stat.	1.345060	

Source: calculated by authors, output from Gretl.

The results of the second step of the analysis prove the existence of energy poverty in Pakistan, depending on the economic development. The latter in turn is influenced by the

BRI, hence the intermittence of economic effects from international infrastructure construction to the Pakistani energy sector is non-direct. The major factors, influencing energy poverty in Pakistan are the rapid growth of population and the lack of FDI in energy sector, partially caused by the high investment risks in the country and the strive for green energy investments from major investors in modern conditions. Despite the several energy projects under the China-Pakistan Economic Corridor [10], their influence on energy sphere is episodic.

Hence, energy poverty in Pakistan is defined by the following factors:

- Traditional demographic model.
- High economic risks, low FDI inflow.
- Non-readiness of the country energy sector for the modern energy generation.
- The lack of direct influence of international institutions and international infrastructure projects on the energy sector.
- The poverty of population and sensitivity of the industrial sector to the energy prices rise.
- Lack of economic support for energy sector development from the public and private sectors.

The acquired results demonstrate a significant issue of energy poverty in Pakistan, which requires to be solved by the implementation of regulation measures and the further development of the country participation in international infrastructure projects.

4 Discussion

The issues of energy poverty are quite developed in some of the regional economies in different aspects, their conclusions are majorly the proof of negative impact of energy poverty on the wellbeing of the citizens of the country [11]. The other research conclusions point on the fact, that BRI and other infrastructure initiatives have significant influence on the national energy policies of the member-countries, as they increase their involvement in the international economic system and trade [12]. The results acquired hereabove generally comply with the previous research on the theme but present the country specifics in energy sphere.

The conclusions allow to present several recommendations on easing the energy poverty in Pakistan. First and foremost, the attractiveness of the country for foreign investors can be increased through the energy sector reforms, namely, the introduction of the green energy transition possibilities for the regions and households in rural regions. These possibilities should include the formulation of propositions for crediting from international institutions for the construction of such facilities in the stable regions of the country.

Secondly, the promotion of cheap energy generation in the urban areas for industrial needs. This includes the construction of coal and oil energy generation facilities near the major cities of the country (provinces' capitals). Simultaneously, the development of nuclear energy is possible too, but in the capital region of the country (near Islamabad) due to the unstable political situation in the separate regions. This measure can be provided through the cooperation with the Chinese financial institutions, especially transnational banks [13], which are interested in the Pakistani energy and services sectors.

Thirdly, the transformation of the waste and biofuel energy facilities to heat generation through subsidies for the share of heat generation on these facilities. This allows the country to provide better energy services for its population and to gradually transform the energy sector in a more reliable and more ecological.

The general recommendations presented above arise from the analysis of the studies on energy issues of Pakistan. The forecast for the industry is rather pessimistic [14], still the

major recommendations, including DSM application [15], MARKAL EnergyPLAN [16] etc. don't contradict the propositions hereabove, just provide specific calculation methods. Still the lack of energy data and reliable energy statistics from the regions of the country limit the possibilities of their application in the current conditions. The future of the green energy in the country remains quite unpredictable too, even though many companies are interested in the participation in such projects in Pakistan [17].

Hence, when speaking of energy poverty in the country, it's persistent, just as in many countries of South Asia, there is no clear solution for its alleviation and the current stage of the Pakistani economic development and risks, present in the country economy don't encourage the economic transformation for the better performance of the energy sector.

5 Conclusion

The article offers a new approach to measuring energy poverty. It's based on the understanding of this issue as the unavailability of stable, reliable, and safe sources of energy generation in the country for internal consumption. As a result, the provided methodology assesses the consumption in the country and imports as the factor of balancing the supply of energy. The developed index allows to measure energy poverty.

When applying the proposed methodology to Pakistan, energy poverty in the country comprises from the lack of energy generation for the economic development of the country, high share of population having no access or limited access to energy sources, unreliable energy generation in the country and the high economic risks, buttressed by the volatile economic performance of the country. In addition to that Pakistan is highly dependent on the international institutions' support for its development, which leaves aside the issues of the social development and the increase in the living standards of its population. The clear result of the mentioned factors is the persisting energy poverty in the country. The international infrastructure projects have nearly no positive impact on energy poverty in Pakistan. It's described by the following performance effects.

The international infrastructure projects the first of which and the most influential is BRI, affect the economic development of Pakistan, thus having a non-direct influence on its energy sector. The infrastructure construction in the country under BRI projects has no direct influence on energy poverty, moreover the construction of energy generating facilities has episodic and non-lasting effect on the energy industry in general.

The energy poverty in the country is persistent due to the economic factors of the country development, listed hereabove. The result of this situation is that the energy sector develops slower than the economy in general, just as the population growth faster than energy supply on the market. The lack of FDI and capital on the Pakistani market limits the possibilities of energy poverty alleviation.

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