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An analysis of the correlation between income and the consumption of energy in Bangladesh

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Abstract

This research takes a methodical look at how rising incomes and climate change affect energy use in six different divisions of Bangladesh. To investigate the indirect mechanism of income influence on the consumption of energy, this study employs indicators of industrial structure upgrading and urbanization in a novel way using the fixed effects model which has not been used so far in this kind of study. The results show that income affects energy use in two ways: directly and indirectly. The influence of income on the consumption of energy is inverted U-shaped and may be readily observed. Furthermore, by encouraging urbanization and upgrading of industrial structure, income can indirectly lower energy use. While energy consumption is negatively impacted by climate change, it is less severe than the effect on earnings. Furthermore, there are substantial geographical and temporal variations in the effect of wealth on energy use. Energy use decreases significantly as income rises over time. Income has a detrimental effect on the consumption of energy in the developed southern area. Energy usage is positively affected by income in the undeveloped northern area. In light of Bangladesh's unique the consumption of energy profile, we must reject the "one size fits all" approach and instead concentrate on reducing wasteful spending in areas like income growth, industrial structure and urbanization, and while simultaneously increasing efficiency and precision in our aiming. This study aims to provide policymakers with fresh insights to inform decisions on energy production and consumption policies considering urbanization and industrial growth.

Keywords: Income, The consumption of energy, Climate change, Urbanization, Industry

Introduction

Modern human civilization is confronted with the most severe energy crisis and climate change issues ever seen. One of the most pressing tasks in creating a global society that can look forward to a shared future is guaranteeing energy security, effective climate administration, and sustainable growth (Sharma et al. 2021). Bangladesh became one of the world's moderate energy consumers and carbon emitters as it achieved outstanding economic success. The international community has taken an interest in the policies and initiatives put forth by the government of Bangladesh to deal with the energy crisis and

the difficulties associated with climate governance. Industrialization and urbanization have not yet reached their full potential in Bangladesh, despite the country's enormous population, substantial industrial framework, and significant GDP (Bangladesh's Economy Is Growing, and So Are Its Emerging Champions 2023). The demands and expectations of citizens for a better life are always rising. The energy demand in Bangladesh is anticipated to remain stubbornly high for the foreseeable future, according to several practical considerations. Particularly difficult to achieve the carbon peak of 2030 and the carbon neutrality goal of 2060 like China is the consumption of energy structure with a high carbon content (Zhao 2022). In order to strategically decrease the consumption of energy and accomplish Bangladesh's dual carbon objectives like China, it is crucial to study the process and trajectory of income change and energy use.

Compared to Sri Lanka and New Zealand in 2021, Bangladesh's energy usage was much greater, according to the BP Statistical Review of World Energy 2022 (71st edition) (Statistical Review of World Energy|Energy Economics|Home, n.d.). In 2019, the total nitrogen oxide emissions for Bangladesh, which include statistics on land-use change and forestry, were recorded as 0.175 metric tons (Bangladesh Total Nitrous Oxide Emissions Including Land-Use Change and Forestry per Capita|Economic Indicators|CEIC, n.d.). Using a lot of energy also makes other kinds of pollution worse (Rahman and Alam 2021). However, Bangladesh has a scarcity of energy resources as a significant portion of its fuel is exported (Shabur 2023). The present situation of high energy and resource consumption and significant environmental pollution is undeniable, even though Bangladesh's economy has sustained fast and robust expansion and environmental degradation is decreasing. Studying the correlation between energy use and economic development is a highly significant study field in Bangladesh because of the profound influence that energy production and consumption have on the country's economic and social development.

Since the 1970s, academics throughout the world have been interested in quantitative studies that try to pin down the exact nature of the connection between wealth and energy use. However, no clear consensus has emerged on the matter. Kraft and Kraft discovered that economic expansion may boost the consumption of energy using yearly information on the United States from 1947 to 1974. In their analyses of the income-the consumption of energy connection, Dzioubinski et al. (1999) and Abakah (1990) found that, as family income rises, the consumption of energy follows a natural progression from fundamental use to sophisticated usage. Using China's census information as well as the Tobit model, Ma et al. (2018) estimated the earnings elasticity of various energy sources for cooking among rural Chinese inhabitants. They found that clean energy had a positive influence on income, whereas solid fuel had a negative effect. Wang et al. (2004) showed that there is a positive correlation between per capita income and per capita the consumption of energy, which increases as per capita income rises. Hui et al. (2006) conducted an analysis on how the income level of farmers affects the structure of energy use of rural households. The analytic hierarchy technique was employed to discern significant disparities in the energy consumption patterns within rural households of varying economic levels. The research cited above establishes a favorable correlation between income and the usage of energy in residential areas. Nevertheless, other research suggests that there is no significant correlation between income and the

consumption of energy. The authors Yu et al. (Eden and Hwang 1984) revised the time period of the United States data to 1947–1979 and discovered that there is no causal connection between energy use and economic development. There is a non-linear relationship between income and the change in energy use, according to Alem et al. (2016). In poor and moderate-income nations, Seema et al. (2017) find that increasing the consumption of energy can boost economic growth, while in high-income countries, they find no such association.

The current worldwide energy crisis, together with the negative effects of non-renewable energy sources on the environment, has hastened the shift towards more sustainable options. Given its vulnerability to the effects of climate change and its reliance on finite fossil fuel supply, Bangladesh must prioritize the creation of a robust and long-term renewable energy policy and regulatory framework. In order to achieve the ambitious goals of reaching zero net carbon emissions and ensuring the long-term sustainability of the country's energy sector, it is absolutely necessary. Therefore it's necessary to study about energy consumption pattern considering different aspects of income, climate change and other related factors.

Income and energy use do not appear to have a clear correlation, according to previous studies. While there is some evidence that wealth has an effect on the consumption of energy, the majority of research has focused on the correlation between the two variables rather than the mechanism by which it does so. Because of this, investigating the connection and process between income and consumption of energy is crucial. As a result, the correlation between income, climate change, and energy use is initially explored in the present research using a fixed effects model. It then delves into the dynamics of urbanization and industrial structure, which are indirect impacts of wealth on energy use. Lastly, the paper presents findings and suggestions derived from empirical research.

However there are still three gaps in the current literature regarding the aforementioned topics. The main issue is that the majority of research only looks at the one-way connection between income and consumption of energy, rather than the two-way process by which income affects energy use in Bangladesh. For example, Uddin and colleagues studied the causal link over time between energy use and economic development in Bangladesh from 1971 to 2007 (Uddin et al. 2011). Miah et al. examined home energy usage, different fuel combinations, and associated costs in the research location. The survey identified biomass, kerosene, electricity, LPG, and candles as the energy sources used in rural homes (Miah et al. 2010). The relationship between household energy use and income in Bangladesh was investigated by Syed Abul Hasan. The results suggest that, up to a certain point in time, households' energy expenditure increases at a slower rate than their income does (Hasan and Mozumder 2017). But they didn't consider climate change, urbanization and industrial structure upgrading in their studies. Joarder et al. conducted an empirical study to analyse the changes in energy intensities by comparing energy consumption per capita and energy consumption per GDP across different industries in Bangladesh over an extended period (Munim et al. 2010). Sima Rani Dey evaluated the causal link between per capita electricity consumption (PCEC) and per capita gross national income (GNI) in Bangladesh from 1971 to 2014. The analysis shows a positive short-run unidirectional causal flow from PCEC to PCGNI without feedback, indicating that high energy usage immediately influences economic activity (Dey 2019).

So it is evident that no study was performed focusing on the correlation between income and energy consumption considering climate change, urbanization and industrial structure upgrading. Moreover, the relationship between wealth, climate change, and energy usage has been the subject of very little research. Using panel data from six main divisions of Bangladesh over a ten-year period (2012–2021), this study systematically investigates the effect of income on the consumption of energy and how it is transmitted. It takes a novel approach by using the process of urbanization and upgrading of industrial structures as parameters to study the influence of earnings on the consumption of energy.

This research makes three significant contributions: To begin with, this article sheds light on the existing literature gap about the link between energy usage ladder and stack by presenting the viewpoint that the consumption of energy exhibits an inverted U-shaped association with income increase. There has been a dearth of research on the break-even points between income and energy usage in the past. The consumption of energy shows an inverted U-shaped association with growth in income, thus we assessed certain change points based on that. Secondly, we incorporate the effects of climate change in the energy usage model and then adjust it to further examine the effect of income on the consumption of energy. According to the research, earnings has a far greater effect on the consumption of energy than climate change does; hence, the main factor influencing the consumption of energy at the moment is the change in income. Raising income affects the consumption of energy in two ways, directly and indirectly, as the study shows in its analysis of the effect process of income on the consumption of energy. Rising incomes have two main effects on power usage: first, they spur urbanization and the improvement of industrial structures, which in turn increase energy demand.

Materials and methods

Methodology and data collection

At the 0.01 level of significance, the results of the Hausman test demonstrate that the null hypothesis has been discarded; there is no correlation between the individual effects and the explanatory factors (Hahn et al. 2011). This research makes use of the fixed effects model for analysis rather than the random effects model due to its superior performance. In order to investigate the effect of a change in income on energy consumption in Bangladesh and the factors that contribute to this effect, an empirical test is necessary, this study uses data from six major divisions in Bangladesh (Dhaka, Chattogram, Rajshahi, Khulna, Sylhet, and Barishal) over 10 years from 2012 to 2021. This research builds the benchmark regression model as Eq. (1) to look at how changes in income affect energy usage in Bangladesh.

$$PCEC_{it} = \alpha_0 + \alpha_1 INCP_{it} + \alpha_2 CL_{it} + \alpha_3 X_{it} + \gamma_t + \delta_i + \varepsilon_{it} \quad (1)$$

For calculating the consumption of energy of divisions, the symbol $PCEC_{it}$ stands for per capita the energy consumption. The income level of provinces and cities may be measured by looking at their per capita income that is disposable, which is $INCP_{it}$. This study is primarily concerned with the influence of income change on the consumption of energy, as measured by the coefficient α_1. It is shown that income development and

climate change would lead to a decrease in the consumption of energy if α_1 stays considerably negative after accounting for various urban characteristic factors. Here CL_{it} represent the climate change factor. To further reduce the impact of missing variables' bias, this analysis accounts for divisions and temporal fixed effects. δ_i represents the mean variation of person-specific means which is constant. γ_t is used to represent fixed effects Lastly, the error term is represented by ε_{it}.

In addition to using the benchmark regression model, this study incorporates a set of climatic and control factors to reduce the impact of missing data on the results. Among these factors is technological advancement (TA), which is a proxy for the amount of patents filed and has a major impact on power usage (Liu and Wang 2014); regulation of the environment (RE), which is demonstrated to decrease the consumption of energy and is assessed by the ratio of regional GDP invested in pollution control for industrial processes to total investment (Zhou and Feng 2017); and the density of the population (DP), which is defined as the number of persons per square kilometer. A substantial association between DP and energy use was discovered by Feng et al. (2017). As mentioned earlier, CL_{it} is a climatic variable that contains both yearly average temperature (TEMP) and relative humidity (RH), and it is used to monitor climate change. A number of studies have shown that energy usage is related to climate change; however, the majority of these studies rely on observational data (Heim et al. 2003; Valor et al. 2001). Greenhouse gas emission, precipitation, sea level rising are also considered as climate change indicator. But due to lack of information, only temperature and relative humidity were only considered as climate change indicator. IS and UI are intermediate variables, indicating the industrial structure and urbanization index respectively. The data and their core statistical explanations of the aforementioned, industrial structure and fundamental explanatory are displayed in the first Table 1. The required information and data utilized in current investigation are predominantly acquired from the Ministry of Power, Energy and Mineral Resources (Energy and Mineral Resources Division-Government of the People\'s Republic of Bangladesh, n.d.) and Population Housing Census 2022, Ministry of Planning (Bangladesh Bureau of Statistics, n.d.). These data was gathered via thorough survey conducted by the Ministry of Bangladesh government. So we can fully rely

Table 1 Parameter description of our model

Parameter	Parameter explanation	Unit	Mean	Standard Deviation	Max	Min
PCEC	Per capita the consumption of energy	100 KWh	6.0876	1.8743	23.2332	4.2345
INCP	Per capita income	100 k BDT	2.86	1.43	7.65	1.22
TA	Technological Advancement (Number of patent granted)	PCs	140	40	240	101
RE	Finished spending money on controlling pollution from industry/Regional GDP	%	0.1120	0.1243	0.956	0.001
TEMP	Yearly average temperature	℃	25.45	7.73	38.2	8.5
RH	Yearly average relative humidity	%	78.63	10.98	90	63
DP	Density of population	Person/km^2	1119.45	856.02	2156	688
UI	Urbanization index	%	0.2567	0.1023	0.5345	0.7458
IS	Industrial structure (Added value of secondary/tertiary industry)	%	1.3155	0.7234	5.322	0.5343

on those data. Otherwise it would be very tough for authors to collect countrywide vast data.

Pearson's correlation coefficient is used to assess the multi-collinearity of independent variables. Table 2 displays the correlation analysis between energy consumption and other variables, revealing a strong positive and statistically significant association at $p < 0.001$.

A Pearson correlation coefficient with an absolute value close to 0.8 indicates the potential presence of collinearity (Shrestha 2020). From Table 2, it is evident that most of the coefficient was greater or nearly equal to 0.8. Therefore, it can be declared that there is a strong correlation among the independent variables which surely boost the robustness of this study.

Results

Effects of income as well as climate change on the consumption of energy

Looking over the results of the Hausman test, we decided against using the random effects model and instead used the double fixed effects framework. Table 3 displays the results of the regression analysis performed on the benchmark regression model-1.

The key and control parameters are added in the regression equations in the first, second and third columns of the table. A substantial drop in energy usage is possible when income rises, according to the shared fundamental factors in first 3 columns. Income significantly reduces energy use, according to the data in the first column. To further corroborate the considerable negative association between income and the consumption of energy, control variables are introduced to column 2 to account for the influence of urban transformation on the consumption of energy. Rising temperatures and relative humidity are major contributors to residents' income, which in turn affects the consumption of energy and climate change. Failing to adequately control for these factors could result in missing parameters and errors, casting doubt on the validity of our study. Column 3 of the regression equation controls for the effect of climatic change by include variations in both relative humidity and temperature. The data show that there is a strong inverse relationship between income and the consumption of energy. The regression findings show that energy usage is negatively affected by income and climate change, and this influence is statistically significant. In addition, income has a far greater effect on the consumption of energy than

Table 2 Pearson's correlation coefficient of independent variables

Variables	INCP	TA	RE	TEMP	RH	DP	UI	IS
INCP	1	0.813	0.789	0.821	0.792	0.832	0.851	0.803
TA	0.813	1	0.773	0.813	0.778	0.823	0.832	0.814
RE	0.789	0.773	1	0.823	0.841	0.832	0.803	0.782
TEMP	0.821	0.813	0.823	1	0.787	0.803	0.817	0.795
RH	0.792	0.778	0.841	0.787	1	0.843	0.767	0.796
DP	0.832	0.823	0.832	0.803	0.843	1	0.832	0.854
UI	0.851	0.832	0.803	0.817	0.767	0.832	1	0.805
IS	0.803	0.814	0.782	0.795	0.796	0.854	0.805	1

Correlation is significant at the 0.01 level (2-tailed)

Table 3 Benchmark regression findings on energy usage, income, and climate change

Parameters	Coefficient (1)	Coefficient (2)	Coefficient (3)	Coefficient (4)
INCP	− 0.9796***	− 0.7932***	− 0.7675***	1.5521***
	(0.3243)	(0.1721)	(0.1543)	(0.3875)
INCP2				− 0.1592***
				(0.0358)
TEMP			− 0.2341**	− 0.1902**
			(0.0974)	(0.0721)
RH			− 0.0497**	− 0.0481**
			(0.0261)	(0.0217)
RE		− 3.5412***	− 3.3648***	− 3.1547***
		(1.1197)	(1.1702)	(1.1012)
TA		− 0.0038***	− 0.0033***	0.0035***
		(0.0013)	(0.0011)	(0.0012)
DP		0.1402**	0.1375**	0.1317**
		(0.0497)	(0.0521)	(0.0523)
_cons	6.1276***	4.5178***	9.9742***	3.3741**
	(0.3871)	(0.5578)	(2.4412)	(1.5542)
Year impact	True	True	True	True
Division impact	True	True	True	True
N	450	450	450	450
R^2	0.1112	0.9612	0.9501	0.9604
Akaike's information criteria (AIC)	790.7412	805.7412	800.8664	798.7441
Bayesian information criteria (BIC)	825.7454	964.7841	969.4682	935.7856

* For 0.1 level of significance

** For 0.05 level of significance

*** For 0.01 level of significance

climate change does, suggesting that money is the principal factor influencing energy use among Bangladeshi inhabitants. So, the main emphasis of the subsequent studies research in the present investigation is on how income affects energy usage and how that influence is transmitted. As an added bonus, all of the model's control variables' coefficients agree well with predictions. A study by Feng et al. also reveals the similar kind of findings in China (Feng et al. 2024). They discovered that income affects energy consumption more than climate change does, indicating that income is the primary factor impacting energy use among those living in China.

Benchmark model-1's linear regression findings demonstrate a substantial relationship between income and energy usage reduction. Does a negative correlation between income and energy use exist at the outset, or does it emerge only once income hits a particular threshold? Adding income as a secondary variable to the benchmark model of regression (fourth column of the Table 2) allows this study to delve more into this subject.

The nonlinear connection that exists between income and the consumption of energy is depicted in Fig. 1, which demonstrates a relationship that is visually represented as an inverted U-shaped curve. With disposable income per capita over 286,000 BDT, a negative association between earnings growth and energy usage is observed, and this negative relationship becomes increasingly apparent as income

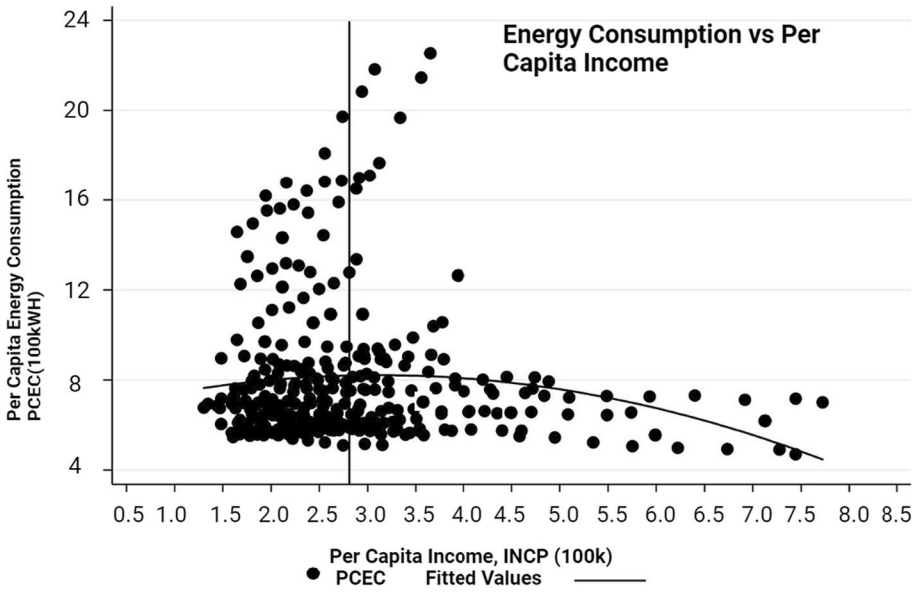

Fig. 1 Scatter diagram of the consumption of energy and income

continues to increase. The regression results in the fourth column of Table 2, which are in accordance with Fig. 1, also show a substantial inverted U-shaped link between income and consumption of energy. Steady with the third column's result in Table 2, the average level of income in Bangladesh now has a negative effect on the consumption of energy. As a result, the linear model remains the foundation for the mechanism analysis of the income-the consumption of energy relationship that follows in this research. Furthermore, the disparity in per capita disposable income between the northern and southern areas of Bangladesh is very considerable, at around 220,000 BDT compared to 350,000 BDT in the southern region. That is why, as you can see in Table 4, the linear model is still utilized for analyzing regional differences.

Table 4's first and second columns show how the constant coefficient varies by location, which reflects how different areas' fundamental the consumption of energy differs obviously according to factors like latitude, the consumption of energy framework, and utilization of energy efficiency. Northern undeveloped regions have a substantially greater constant coefficient than southern developed regions, suggesting that northern regions have a stronger foundation of fundamental household energy usage.

Additionally, as can be seen from columns 1 and 2 of Table 4, the impact of income growth on the consumption of energy is more pronounced than that of climate change; hence, inhabitants of Bangladesh are primarily driven to alter their home the consumption of energy by increases in wealth. There is a lack of consistency in the direction of change and substantial regional variation in the effect of income on energy usage. Table 4, first column, shows that in the developed southern area, the consumption of energy is negatively affected by income growth and positively affected by climatic change. In the underdeveloped northern area, the consumption of energy is positively affected by wealth, and negatively affected by variations in temperature

Table 4 Results of regression analysis examining variations in climate change, income, and consumption of energy across different regions and time periods

Parameters	Region		Year	
	South coefficient-1	North coefficient-2	2012–2016 coefficient-3	2017–2021 coefficient-4
INCP	− 0.7743***	5.0432**	− 0.4512***	− 1.1521***
	(0.1689)	(2.3876)	(0.1643)	(0.3075)
TEMP	− 0.1239	− 0.1239	− 0.1239	− 0.2012
	(0.1192)	(0.1262)	(0.0495)	(0.1196)
	− 0.0045	− 0.1191**	− 0.0132	− 0.0512
	(0.0201)	(0.0511)	(0.0134)	(0.0331)
	0.8512	− 4.3123***	0.7512*	− 5.6012***
	(1.5512)	(1.3495)	(0.3901)	(1.8023)
	− 0.0017	− 0.0351**	− 0.0050**	− 0.0019*
	(0.0013)	(0.0171)	(0.0018)	(0.0014)
	0.0812	0.1337**	− 0.0406	0.2920***
	(0.0662)	(0.0704)	(0.0298)	(0.0803)
	6.4134**	15.9457***	4.9745***	12.9234***
	(2.5321)	(5.0267)	(1.5023)	(3.6732)
Year impact	True	True	True	True
Division impact	True	True	True	True
N	270	180	230	220
R^2	0.9514	0.9562	0.9867	0.9642
Akaike's information criteria (AIC)	345.8743	375.7345	130.4536	355.8732
Bayesian information criteria (BIC)	449.7643	451.5673	250.6746	469.7446

* For 0.1 level of significance,

** For 0.05 level of significance,

*** For 0.01 level of significance

and relative humidity, according to the regression findings shown in Table 3's second column. This is due to a number of factors, the most important of which are the following: low resident incomes, a poor climate, a large temperature difference, a high demand for energy, and the fact that residents' the consumption of energy increases in direct proportion to their income.

Developed communities in the southern region have moderate climates, high incomes, and a population that is more open to using environmental preservation to better their lives. Consequently, when people's income rises, they tend to use less energy. The upward trend in the adverse effect of rising incomes on the consumption of energy over time, as seen in the columns 3 and 4 of Table 4, suggests that residents' demand for energy falls and increases with rapid economic development. On the other hand, the underdeveloped northern region have critical climate, low incomes and population with low education who are not concerned about the preservation of energy. Usually it is observed that northern part of Bangladesh faces extreme cold and hot in winter and summer season respectively. That's why they need more energy in both seasons to overcome that extreme situation. This situation also verified by our findings which show that northern part has a more energy consumption than southern part. This difference in energy use also brings some socioeconomic and cultural

variations between two regions. Most of the industrial development are based on southern part which uplift the economic condition of the population of southern part. In contrast, northern part remains underdeveloped with low educational percentage.

The transmission mechanism between income and the consumption of energy

Based on the data shown above, it is clear that income/earnings has an adverse influence on the usage of energy in Bangladesh. Similar findings was found by some Chinese researchers. According to their findings, income/earnings has a negative impact on the consumption of energy in China (Feng et al. 2024).How does a country's GDP impact its energy use in Bangladesh? Using prior studies as a guide, this section will analyze how urbanization and improvements to Bangladesh's industrial structure impact the consumption of energy as a function of changing income.

Consumption of energy and income: the mechanism of urbanization

Energy usage can be influenced by changes in income as a result of urbanization. Rising incomes and urbanization go hand in hand; the former raises demand for goods and services, the latter boosts consumption, and the former increases the consumption of energy and carbon emissions (Bakirtas and Akpolat 2018; Wang et al. 2022). Domestic the consumption of energy also rises as a result of urbanization as people's lifestyle standards become more in line with the more energy-intensive urban dwelling model. The idea that urbanization reduces people's energy use is countered by some (Wang et al. 2018). Urbanization also causes a rise in home the consumption of energy because it forces people to conform their living standards to those of the more energy-intensive urban residential model.

The idea that urbanization reduces people's energy use is countered by some. According to these scholars, urbanization is an intense process in and of itself, and the positive impacts of agglomeration and scale in regulating residents' the consumption of energy mitigate the negative consequences of population expansion on this parameter (Rahman and Alam 2021; Yang and Khan 2022).

This study used the four indicators of urbanization, namely economic growth, growth of the population, ecological environment and public facilities, as proxy variables to validate this process. The results of the empirical regression are shown in Table 5. The minus regression coefficient of urbanization components in Table 4's first column provides evidence that urbanization significantly reduces energy usage. The presence of a positive connection in the income variable of Table 5's second column indicates that rising incomes have spurred urbanization, which in turn has decreased energy use. Both the direct effect of income changes on the consumption of energy and the indirect effect of income changes on urbanization are demonstrated here. It is worth mentioning that by enhancing RE and TA, the consumption of energy may be reduced in two ways: directly, by facilitating urbanization, and indirectly, by reducing the consumption of energy overall. But DP does two things: it increases the consumption of energy directly and it promotes urbanization, which in turn decreases the consumption of energy indirectly. The direct and indirect overall effects of DP on the consumption of energy are thus responsible for its influence.

Table 5 How urbanization and industrial structure affect the consumption of energy and income

Parameters	PCEC Coefficient	UI Coefficient		PCEC Coefficient	IS Coefficient
UI	− 7.4734**		IS	− 1.5103***	
	(3.3743)			(0.4532)	
INCP		0.0271***	INCP		0.2898***
		(0.0053)			(0.0352)
TEMP	− 0.2302**	0.0006	TEMP	− 0.2580***	− 0.0204
	(0.0939)	(0.0015)		(0.0956))	(0.0159)
RH	− 0.0461*	0.0012***	RH	− 0.0639**	− 0.0066*
	(0.0258)	(0.0003)		(0.0267)	(0.0034)
RE	− 3.4502***	0.0161*	RE	− 3.2993***	0.1389*
	(1.1831)	(0.0089)		(1.1055)	(0.0828)
TA	− 0.0022	0.00025***	TA	− 0.0048***	− 0.0007***
	(0.0016)	(0.00011)		(0.0015)	(0.0002)
DP	0.1350**	0.0016***	DP	0.1251**	− 0.0025
	(0.0529)	(0.00039)		(0.0497)	(0.0044)
_cons	9.2404***	0.1981***	_cons	14.1869***	3.6706***
	(2.5512)	(0.0410)		(3.5718)	(0.3559)
Year impact	True	True	Year impact	True	True
ID impact	True	True	ID impact	True	True
N	450	450	N	450	450
Adjusted R^2	0.9602	0.9779	Adjusted R^2	0.9704	0.9685
Akaike's Information Criteria (AIC)	810.7493	− 1658.5637	Akaike's Information Criteria (AIC)	795.8747	− 403.5843
Bayesian information criteria (BIC)	974.9771	− 1546.6643	Bayesian information criteria (BIC)	960.4773	− 235.0984

Furthermore, variations in relative humidity can have an indirect and direct impact on energy use, and climate change can have the same effect. Efficiency in energy use, conservation of water, greening of urban areas, and the use of renewable energy sources may all be advanced by the establishment of rules and regulations. We can lessen our impact on the environment, enhance air quality, and reap several other advantages for your community by implementing these measures.

Consumption of energy and income: the mechanism of industrial structure

Industrial structure upgrading is another significant way that economic prosperity might impact energy use. The initial evidence that shifts in the composition of industries affect energy usage came from Meadows et al. (1972). Consequently, based on their study and analysis of various nations, a number of experts came to the conclusion that the shift in industrial structure significantly impacted the consumption of energy (Ahmed and Zeshan 2014; Jung and Park 2000; Narayanan and Sahu 2014). The consumption of energy intensity follows an inverted U-shaped pattern as industrial structure advances, as previously shown by Malenbaum (n.d.). The method of meeting societal demand for the consumption of energy upgrades was further upon by Frei (2004). Furthermore, several researchers have used empirical methods to investigate the connection between the structure of energy use and the structure of industries (Schurr et al. 1960; Zhou et al. 2010). In this study, we empirically test the influence of the industrial structure

mechanism on earnings affecting the consumption of energy by using the proportion of postsecondary and secondary industries as the proxy parameter for the upgrading of industrial structure. This variable is widely used in the literature and allows us to further investigate the effect of the process of industrial structure upgrading on changes in the consumption of energy.

The transmission process of industrial structure is confirmed by the regression findings in the third and fourth columns of Table 5. Upgrading industrial structures may lower the consumption of energy, as shown in Table 4 column 3, and increased income levels can encourage this upgrade, as shown in the column 4 of Table 5, suggesting that an increase in income/earnings can stimulate upgrading of industrial structure, which in turn reduces the consumption of energy. All of the preceding shows that raising people's incomes may lower the consumption of energy in two ways: first, by encouraging the upgrading of industrial structures, and second, by lowering energy use directly. There are both immediate and long-term effects of climate change on energy usage. Alterations to the relative humidity have a dual effect: lowering the consumption of energy directly and raising it indirectly through the advancement of industrial structure upgrades. As a result, both the direct and indirect impacts of relative humidity on the consumption of energy must be considered together. In addition, the consumption of energy is affected, either directly or indirectly, by RE, TA, and DP.

To mitigate the negative impact of industrial structure upgrading on energy consumption, we can initiate some industrial energy efficiency policy (Cagno et al. 2013). Industrial energy efficiency refers to the use of various technologies, techniques, and business practices to decrease the energy consumption levels in production. Among the many possible motivations for a business to cut its energy consumption are: growing utility bills, an increase in the rate of inflation, concerned about the environment, boosting competitiveness in the market (Worrell et al. 2018). If we want to make the economy stable Energy prices will always be there, but we can drastically cut back on our consumption. Practical energy reductions of around 20% are achievable for facilities, with 30% of that amount being saved via changes in procedure and behavior alone, according to energy.gov (Department of Energy, n.d.) No physical investment is required. We will become the lean industry leaders by increasing productivity and profitability through energy efficiency improvements.

Tests for checking robustness

To verify this claim, Table 5 shows that wealth can influence energy use indirectly via mechanisms related to urbanization and industrial structure. Utilizing the mechanism of industrial structure as an example, this section further verifies this mechanism by employing a mediating effect model. Table 5 displays the specific outcomes.

We begin by constructing the model according to a three-step procedure for identifying the mediating effect (Zhonglin and Baojuan 2014), that will enable us to validate the process of upgrading the industrial infrastructure and the effect of earnings on usage of energy:

$$IS_{it} = \alpha_{20} + \alpha_{21}INCP_{it} + \alpha_{22}CL_{it} + \alpha_{23}X_{it} + \gamma_t + \delta_i + \varepsilon_{it} \quad (2)$$

$$PCEC_{it} = \alpha_{30} + \alpha_{31}INCP_{it} + \alpha_{22}CL_{it} + \alpha_{34}X_{it} + \gamma_t + \delta_i + \varepsilon_{it} \quad (3)$$

Upgrading industrial structures is the mediating parameter in the first, second, and third Models, which are mediating-effect models. IS_{it} is one of these variables. Income significantly affects the consumption of energy, which is necessary for the mediating effect to be established, assuming α1 in model-1 is non-zero and substantial. We shall not run any additional tests if α_1 is not statistically significant. In model-2, a substantial α_{21} and in model-3, a weighty α_{32} indicate that the effect of mediating is true. Additional examination is necessary if neither α_{21} nor α_{32} is statistically significant.

Table 6, column 1, shows the estimated results of the income influence coefficient on energy consumption, which support the mediating effect analysis's benchmark assumption, that there is a 1% significant reduction in energy usage with an increase in income. Then, we'll take a look at how money gets passed on by encouraging the upgrading of industrial structures and reducing energy use. It is clear that income may successfully encourage industrial structure upgrading, as shown in Column-2 by the considerably positive influence coefficient of income on this variable. It is evident from the third column that earnings has a substantially adverse influence on energy consumption via stimulating industrial structure upgrades, which in turn lowers energy usage. Since the income influence on the consumption coefficient in third column is smaller than in

Table 6 Mediating effect model for the industrial structure's income and consumption of energy process

Parameters	PCEC Coefficient of First Model	IS Coefficient of Second Model	PCEC Coefficient of Third Model
IS			− 1.1593
			(0.5205)
INCP	− 0.7663***	0.2964***	− 0.4534**
	(0.1564)	(0.0343)	(0.1921)
TEMP	− 0.2268**	− 0.0204	− 0.2504**
	(0.0970)	(0.0161)	(0.0969)
RH	− 0.0530**	− 0.0067*	− 0.0611**
	(0.0262)	(0.0029)	(0.0271)
RE	− 3.3801***	0.1393*	− 3.2235***
	(1.172)	(0.0831)	(1.1203)
TA	− 0.0029***	− 0.0006***	− 0.0039***
	(0.0011)	(0.0003)	(0.0014)
DP	0.1378***	− 0.0026	0.1348***
	(0.0526)	(0.0042)	(0.0498)
_cons	9.9606***	3.6698***	14.2201***
	(2.4467)	(0.3623)	(3.5643)
Year impact	True	True	True
ID impact	True	True	True
N	450	450	450
Adjusted R^2	0.9623	0.9703	0.9619
Akaike's Information Criteria (AIC)	798.0983	− 404.5937	796.6338
Bayesian Information Criteria (BIC)	968.6362	− 230.8744	965.8827

first column, we may infer that upgrading of industrial structure partially mediates the relationship between energy consumption and income. As a result of more disposable money going into structural improvements in manufacturing, the tertiary sectors have grown at a faster rate. This sector uses far less energy than the secondary sector, further cutting down on energy usage. So far, we have confirmed that income and the consumption of energy are both involved in the mechanism of industrial structure upgrading, which means that a greater income can lead to a decrease in the consumption of energy through the promotion of industrial structure upgrading.

Figure 2 displays the key findings from this research. One interesting finding is that income and the consumption of energy follow a strong inverted U-shaped connection. Another interesting finding is that there are notable disparities in both regional and temporal variability. Secondly, urbanization is an indirect way in which income impacts energy usage.

The last factor is income, which influences energy usage indirectly via the structure of industries.

This study can suggest a guideline for policymaker to take action about energy policy and climate change. It is observed that climate change plays a negative role in energy consumption. Because more energy is needed to mitigate the negative effect of climate change. It becomes more colder in winter and more hotter in summer. So we have to move towards renewable and sustainable energy sources.

Discussion

Income has a beneficial influence on the consumption of energy, according to previous studies in Asia (Chen et al. 2022; Nguyen-Van 2010). After reviewing all of the research in this area, this study found that wealth has an effect on energy consumption in Bangladesh, although it does not merely reflect a rising or declining trend. The effect of income on the consumption of energy undergoes a reversal from positive to negative at a specific critical income level, indicating that this relationship is nonlinear. Furthermore, while many studies have looked at how money affects the consumption of energy, very few have looked at how income affects the consumption of energy and the path it takes to be

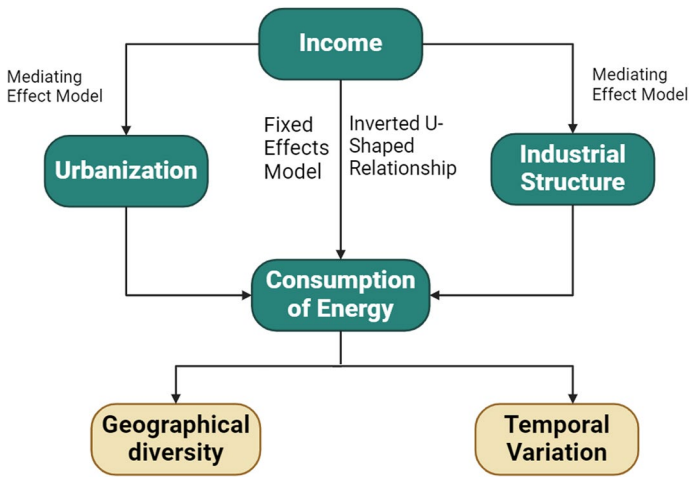

Fig. 2 Key findings of this research

transmitted. As a result, we'll take a look at how urbanization and upgrading of industrial structures are elements in the process of transmission of income change influencing the consumption of energy in Bangladesh.

Furthermore, the correlation between monetary wealth, energy use, and climate change has been the subject of scant investigation. While there is some evidence linking energy usage to global warming, the majority of this study relies on observational data (Heim et al. 2003; Valor et al. 2001). On the one hand, studies in this area have mostly looked at the correlations among income, energy usage, and climate change; on the other, the mechanisms and transmission pathways between these three variables have received far less attention. In addition, the study concludes that energy usage is significantly affected by climate change. This will serve as the foundation for future studies that explore the interplay among income, energy usage, and climate change.

Insights and implications of policy

Conclusion

Rapid economic growth, rising incomes, and vastly better living conditions have all been hallmarks of Bangladesh in recent years. Environmental degradation due to human-caused economic growth is known as climate change and global warming. Consumption of energy and pollution often go hand in hand; as a result, the people of Bangladesh get the benefits of economic progress while also bearing the burden of environmental harm. This is especially true in light of the fact that household the consumption of energy has grown to constitute a significant portion of both. Therefore, in order to help Bangladesh improve its energy development plans and reach its carbon emission reduction targets, it is crucial to study the particular elements and processes that affect the country's the consumption of energy.

This study has three primary findings. To start, the present the consumption of energy in Bangladesh is greatly impacted negatively by poverty and climate change. The consumption of energy changes due to wealth have a far larger impact than climate change. Recent studies have shown that when income fluctuates significantly, the correlation between earnings and energy usage does not follow a straight line from positive to negative. Rather, it reveals an inverted U-shaped pattern that indicates that there will be a considerable effect of earnings on energy usage during periods of substantial income fluctuation, first increasing and then decreasing the consumption of energy. Secondly, there are large temporal and geographical variations in the effect of income on energy use in Bangladesh. When it comes to the wide disparity in income between regions in Bangladesh, the poorer parts of the country's northern half have a markedly positive influence of income on their consumption of energy, while the wealthier parts of the country's southern half see a markedly negative impact. Moreover, the negative effect of earnings on the usage of energy grows as economies expand and income levels rise, as these factors make it possible to decrease energy usage at a faster rate.

Lastly, income has a substantial impact on energy usage, both directly and indirectly. Directly, a rise in wealth can reduce the consumption of energy; indirectly, it can encourage urbanization and the upgrading of industrial structures, both of which lower energy use. The mediating effect hypothesis provides more evidence that wealth has an influence on the consumption of energy through a process involving the industrial structure.

Policy implications

Policymakers should take note of the study's findings. When compared to the consumption of energy range generated by climate change, the range created by growth in income is much larger. This indicates that rising incomes are the main driver behind the decrease in energy use per capita in Bangladesh. With the country's economy booming and people's living standards steadily rising, climate change isn't going to have much of an effect on Bangladesh's the consumption of energy. In the future, though, citizens will be more inclined to embrace green practices in order to regulate the climate, and the country's the consumption of energy percentage is predicted to drop significantly. Energy use in daily life is getting better as the dual carbon strategy is being put into place more and more. As a result of climate change, household the consumption of energy in Bangladesh will shift from being driven by income development, as it is in affluent nations now, to being driven by other factors. The goal here should be for lawmakers to push for a shift in the energy system's architecture, with an emphasis on greater efficiency and the widespread adoption of green and renewable energy practices.

Solar power, wind power, and other renewable energy sources should be actively promoted and used in all aspects of life. The consumption of energy increases in Bangladesh show geographical patterns as a function of economic development; these patterns are associated with differences in living conditions across and even within areas. Consequently, it is critical to raise local people's incomes and implement suitable price subsidy programs to make sure that every household can utilize green energy in regions that are economically developing more slowly than the north. In order to promote sustainable energy development, increase efficiency in energy usage, and actively advocate for low-carbon consumption, economically developed southern areas must analyze and prioritize their consumption of energy structure. On top of that, if urbanization is encouraged and industrial structures are upgraded, Bangladesh's the consumption of energy may be further reduced, and sustainable development can be advanced. This will serve as a foundation for further investigations into how and why climate change affects energy use and the improvement of energy infrastructure.

Another important point to be noted that this study reveals a clear variation in energy use between northern and southern region of Bangladesh. Policymakers should focus on this issue to mitigate this variation so that both region can grow industrially and economically in a same manner in consuming energy and other factors.

Limitations

Some limitations are included in the results of this investigation. Although the effects of wealth and climate change on the consumption of energy on a macro level have been covered in this study, more discussion is needed considering other issues theoretical assumptions. We have used fixed effects model in our study. Further study may include random effects model and compare their results with us. Secondly, the influence of climate change on the consumption of energy has not been thoroughly investigated in this study, only temperature and relative humidity have been considered; hence, future research can delve more into these questions. The next issue is that the data is limited which was provided by the Ministry of Bangladesh, therefore this analysis can only

account for a subset of the economic factors like education and training, inflation, natural resources etc. that affect energy use. Energy usage is still affected by non-economic variables like population structure. Consequently, in order to investigate the effect of noneconomic variables on energy use, additional research can be performed. Moreover, new avenues for future research can be longitudinal studies or comparative analyses with other countries.

Author contributions
Md. Abdus Shabur: conceptualization, methodology, software, investigation, writing—original draft preparation, Md. Farhad Ali: review and editing.

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Availability of data and materials
The datasets generated during and/or analyzed during the current study are not publicly available due to these data have been collected from the Ministry of Bangladesh which contains confidential information of citizens, but are available from the corresponding author upon reasonable request.

Declarations

Ethical approval and consent to participate
This study was approved by Research Center, University of Dhaka. The approval number is DU/RC/2024-009 which certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent for publication
Not applicable.

Competing interests
There is no financial competing interests in this research.

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