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The Validity of Electricity Consumption as an Indicator for Economic Evaluation: Cross-Country Analysis

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Abstract: This article aims to investigate the validity of using electricity consumption as an indicator to evaluate economic conditions and explore the relationship of this indicator across different countries. The study reveals a positive correlation between electricity consumption and the growth rate of Gross Domestic Product (GDP), which becomes more significant in the post-21st century period for middle-income, high-income countries, and globally. The relationship between the growth rate of industrial value-added and electricity consumption exhibits dynamic variations. It weakens for lower-middle-income countries but strengthens for upper-middle-income and high-income countries in the post-21st century. Moreover, there is a strong positive correlation between the logarithm of GDP and the logarithm of electricity consumption, particularly pronounced for high-income countries, with a significant increase in correlation in the 21st century. Similarly, a strong positive correlation exists between the logarithm of industrial value-added and the logarithm of electricity consumption, especially notable for high-income countries where the correlation further intensifies in the post-21st century. In conclusion, electricity consumption can serve as an effective indicator for evaluating economic conditions, with its relationship to economic growth and industrialization influenced by the income level of countries.

Keywords: electricity consumption, economic conditions, Gross Domestic Product, industrial value-added, income level

1. Introduction

Evaluating the economic conditions of countries is of paramount importance in understanding their development and making informed policy decisions. Traditional economic indicators, such as Gross Domestic Product (GDP), have long been used to assess economic performance. However, concerns have arisen regarding their comprehensive and accurate representation of a country's economic health. With the rapid development of economy, the electricity consumption is also increasing. The increase of electricity consumption has further promoted the progress of the industrial economy [1]. In recent years, electricity consumption has emerged as a potential alternative economic indicator, attracting attention from researchers and policymakers alike.

One intriguing case that has raised questions is the United States, where a decline in electricity consumption has coincided with GDP growth. This apparent discrepancy challenges the conventional understanding of the relationship between energy consumption and economic performance. It prompts us to explore the effectiveness of using electricity consumption as an indicator of economic conditions and to uncover the underlying factors driving this divergence.

Another noteworthy case is the Chinese economy. As a major global player, accurately assessing China's economic conditions is essential for understanding its trajectory and potential impacts on the global economy. The Li Keqiang Index, which incorporates factors such as electricity consumption, rail freight volume, and loan disbursements, has gained attention as an alternative measure for evaluating China's economic performance. However, the effectiveness of this index, particularly in relation to electricity consumption, warrants further investigation.

The objective of this study is to examine the validity of using electricity consumption as an indicator to evaluate economic conditions across various types of countries By analyzing electricity consumption data and other relevant economic indicators from different countries, this paper aims to determine the extent to which electricity consumption can provide valuable insights into economic conditions.

Through this research, this paper anticipates shedding light on the potential of electricity consumption as an economic indicator and enhancing our understanding of its applications across diverse national contexts. The findings will not only contribute to the academic understanding of economic evaluation but also provide policymakers with valuable insights to make informed decisions based on a more comprehensive assessment of a country's economic conditions.

2. Regression analysis

By selecting the electricity generation, industrial value-added, and GDP growth data of the following countries, it can be observed that there is a certain correlation between the growth of GDP and industrial value-added, and the increase in electricity consumption in many countries, as shown in figure 1, figure 2, figure 3, figure 4.

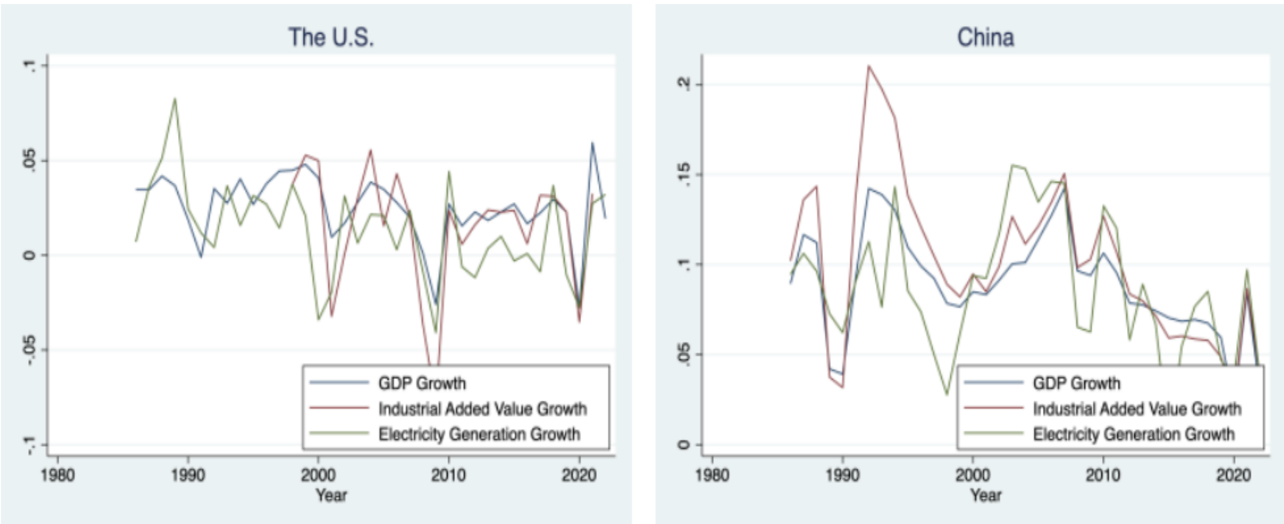

Figure 1: China and The US

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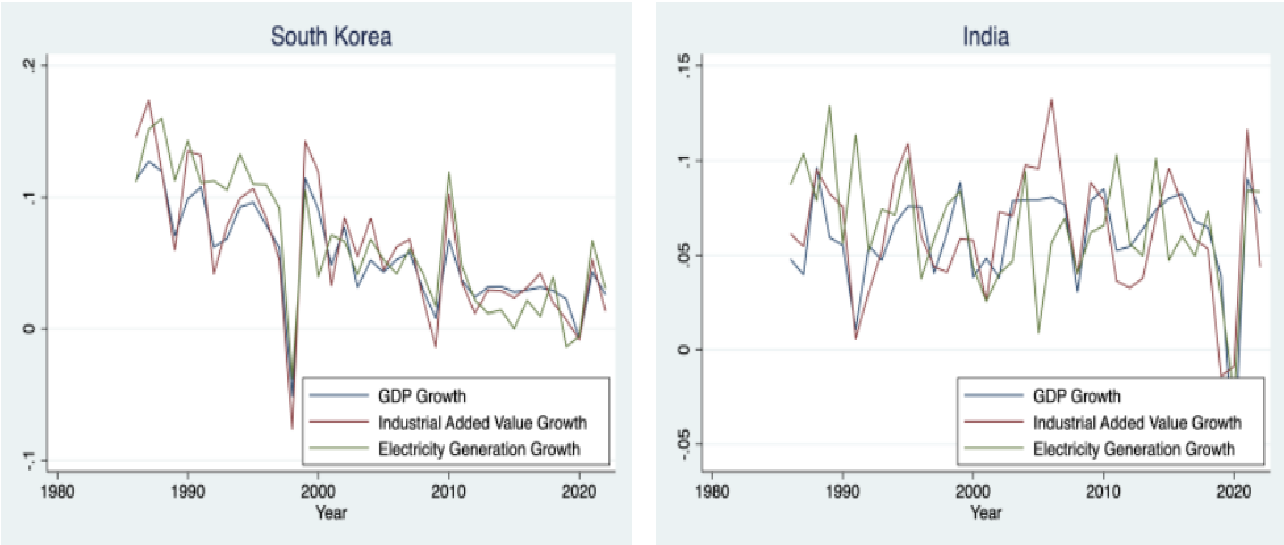

Figure 2: South Korea and India

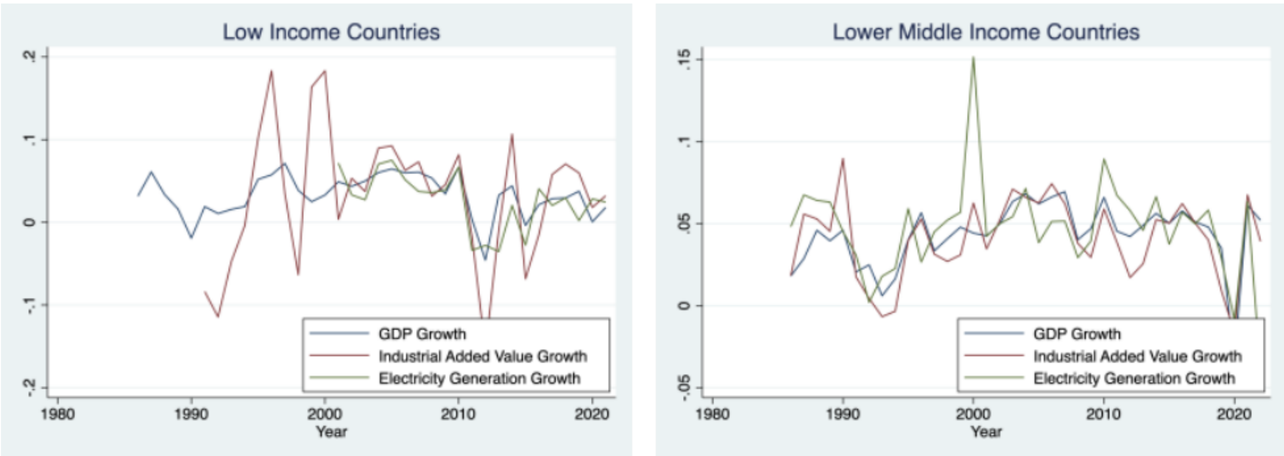

Figure 3: Low and Lower Middle Income Countries

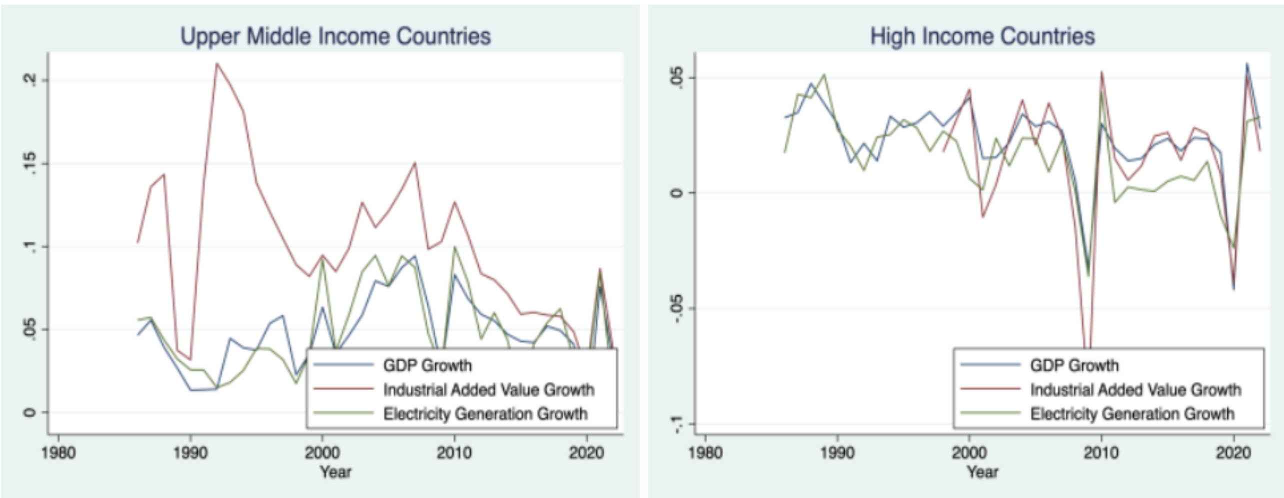

Figure 4: High and Upper Middle Income Countries

In this paper, the electricity generation, GDP and industrial added value of many countries from 1985 to 2022 are selected for regression analysis [2-4].

2.1. On Countries of Different Wealth

Regression analysis is first conducted on the sum of countries of the same income level.

First regress the growth rates of GDP and industrial value-added on the growth rate of electricity generation for three periods: pre-21st century, post-21st century, and the overall data.

$$GDP\ growth\ rate = k \times electricity\ generation\ growth\ rate + b \tag{1}$$

$$Industrial\ value\ added\ growth\ rate = k \times electricity\ generation\ growth\ rate + b \tag{2}$$

Then, regress the logarithms of GDP and industrial value-added on the logarithm of electricity generation to observe the relationship between these economic indicators' growth and electricity data.

$$GDP\ logarithms = k \times electricity\ generation\ logarithms + b \tag{3}$$

$$Industrial\ value\ added\ growth\ rate = k \times electricity\ generation\ growth\ rate + b \tag{4}$$

The above regression uses two methods to explore the forecasting strength of electricity consumption on economic indicators

Then, the coefficient of GDP regressions are regressed on the average and standard deviation of the industrial share in the two periods before and after the 21st century and the overall industrial share, in order to explore the impact of the industrial share on the forecast effect of electricity consumption

$$Coefficient\ of\ GDP = k \times industrial\ share\ average + b \tag{5}$$

$$Coefficient\ of\ GDP = k \times\ industrial\ share\ standard\ deviation + b \tag{6}$$

Table 1: Upper-middle-income, High Income and world growth rates.

	Upper-middle-income		High Income		World	
	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|
GDP Growth rate (before 2001)	0.568	0.005	0.252	**0.232**	0.353	0.110
Growth rate of Industrial output (before 2001)	0.624	**0.390**	1.187	0.217	0.831	0.126
GDP growth rate (after 2001)	0.706	0.000	0.898	0.000	0.902	0.000
Growth rate of industrial output (after 2001)	0.937	0.000	1.349	0.000	1.292	0.000
GDP growth rate	0.699	0.000	0.750	0.000	0.785	0.000
Growth rate of industrial output	0.241	**0.392**	1.289	0.000	1.172	0.000

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Table 2: Upper-middle-income, High Income and world logarithms.

	Upper-middle-income		High Income		World	
Natural logarithm of GDP (before 2001)	1.096	0.000	1.078	0.000	1.068	0.000
Natural logarithm of industrial output (before 2001)	3.765	0.000	1.488	0.090	1.190	0.000
Natural logarithm of GDP (after 2001)	0.998	0.000	2.282	0.000	0.973	0.000
Natural logarithm of industrial output (after 2001)	1.542	0.000	1.696	0.000	0.989	0.000
The natural log of GDP	0.987	0.000	1.472	0.000	1.043	0.000
The natural logarithm of industrial output	1.936	0.000	1.517	0.000	1.012	0.000

Table 3: Lower income level categories growth rates.

	Low-income		Lower-middle-income	
	Coef.	P>|t|	Coef.	P>|t|
GDP Growth rate (before 2001)	-	-	0.178	**0.116**
Growth rate of Industrial output (before 2001)	-	-	0.440	0.028
GDP growth rate (after 2001)	0.595	0.000	0.412	0.009
Growth rate of industrial output (after 2001)	1.165	0.001	0.417	0.016
GDP growth rate	0.595	0.000	0.270	0.013
Growth rate of industrial output	1.165	0.001	0.413	0.001

Table 4: Lower income level categories logarithms.

	Low-income		Lower-middle-income	
Natural logarithm of GDP (before 2001)	-	-	0.776	0.000
Natural logarithm of industrial output (before 2001)	-	-	0.750	0.000
Natural logarithm of GDP (after 2001)	1.394	0.000	1.002	0.000
Natural logarithm of industrial output (after 2001)	1.225	0.000	0.878	0.000
The natural log of GDP	1.348	0.000	0.912	0.000
The natural logarithm of industrial output	1.174	0.000	0.834	0.000

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Based on the information provided in the table 1, table 2, table 3. table 4, an analysis can be conducted on the relationship between GDP growth rate and electricity consumption growth rate across countries with different income levels. Overall, there is a positive correlation between GDP growth rate and electricity consumption growth rate. This positive correlation has strengthened in the post-21st century period for lower-middle-income countries, upper-middle-income countries, and high-income countries. Specifically, for upper-middle-income countries, the positive correlation has remained relatively stable before and after the 21st century, while for high-income countries, the positive correlation has significantly increased in the 21st century. From a global perspective, the positive impact of GDP growth rate on electricity consumption growth rate has strengthened after the 21st century.

There are certain dynamic variations in the relationship between industrial value-added growth rate and electricity consumption growth rate. The positive correlation between them has decreased for lower-middle-income countries, while it has strengthened for upper-middle-income countries and high-income countries after the 21st century. For upper-middle-income countries and high-income countries, the previously negative correlation before the 21st century has undergone significant changes and transformed into a significant positive correlation in the post-21st century period. Globally, the positive impact of industrial value-added growth rate on electricity consumption growth rate has significantly increased after the 21st century.

These results indicate that the driving effect of industrialization on electricity consumption varies with the increase in a country's income level. There exists a strong positive correlation between the logarithm of GDP and the logarithm of electricity consumption across countries with different income levels. This correlation exhibits the following characteristics for different income-level countries: for lower-middle-income countries and similar income-level countries, this positive correlation has strengthened before and after the 21st century. For upper-middle-income countries and similar income-level countries, the positive correlation was stronger before the 21st century but experienced a slight decrease after the 21st century. For high-income countries, the positive correlation has significantly increased after the 21st century, showing a stronger positive relationship. From a global perspective, the positive correlation between the logarithm of GDP and the logarithm of electricity consumption has slightly decreased after the 21st century but still remains at a relatively high level.

There exists a strong positive correlation between the logarithm of industrial value-added and the logarithm of electricity consumption. This correlation exhibits the following characteristics across countries with different income levels: for lower-middle-income countries and similar income-level countries, this positive correlation has strengthened before and after the 21st century. For upper-middle-income countries and similar income-level countries, the positive correlation was stronger before the 21st century but has slightly decreased after the 21st century. For high-income countries, the positive correlation has remained strong both before and after the 21st century, with a further strengthening trend. From a global perspective, there has been a slight decrease in the positive correlation between the logarithm of industrial value-added and the logarithm of electricity consumption after the 21st century.

Table 5: Regression coefficients of GDP for countries of different income groups on the data of the proportion of industry.

	GDP Growth Rate		GDP Logarithm	
	Coef.	t	Coef.	t
Share of industrial output value Mean	-1.207	**-0.6***	-6.403	-2.57
Share of industrial output value Std. Dev.	-3.235	**-0.23***	9.945	**0.46***

(The T-value with * means that it is not significant at the 0.05 level)

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As shown in table 5, regarding the impact of the share of industrial value-added on the regression coefficients, this study found a negative correlation (-1.207) between the GDP growth rate and the regression coefficient of electricity consumption growth rate, with respect to the average share of industrial value-added. Similarly, the regression coefficient between the logarithm of GDP and the logarithm of electricity consumption (-6.403) is also negatively correlated with the average share of industrial value-added. This indicates that for economies with a higher level of industrialization, GDP variations are less influenced by electricity consumption.

From the regression data from 1985 to 2022, several patterns and trends can be observed regarding the country's income level:

1. Regression coefficient of GDP growth rate on electricity consumption growth rate:

As the country's income level increases, this coefficient shows a gradual upward trend. It is 0.595 for low-income countries, 0.412 for lower-middle-income countries, 0.706 for upper-middle-income countries, and 0.898 for high-income countries. This indicates that countries with higher levels of economic development experience a stronger pull of GDP growth from electricity consumption growth.

2. Regression coefficient of industrial value-added growth rate on electricity consumption growth rate:

For low-income countries and lower-middle-income countries, this coefficient is relatively high at 1.165 and 0.417, respectively. For upper-middle-income countries and high-income countries, the coefficient starts as negative and then becomes positive, measuring 0.937 and 1.349, respectively. This suggests that in developing countries where industrial sector plays a significant role in the economic structure, the impact of industrial value-added growth on electricity demand growth is more pronounced. In high-income countries undergoing economic structural transformation, the role of industry becomes more complex.

3. Regression coefficient of logarithm of GDP on logarithm of electricity consumption:

With the increase in the country's income level, this coefficient initially rises and then declines, reaching a peak of 2.282 for upper-middle-income countries. This indicates that larger economies have a closer relationship between GDP and electricity consumption, particularly during the middle-income stage.

4. Regression coefficient of logarithm of industrial value-added on logarithm of electricity consumption:

This coefficient also shows a pattern of first decreasing and then increasing with the increase in the country's income level, reaching a peak of 1.696 for high-income countries. This suggests that countries with higher income levels have a stronger correlation between the industrial sector and electricity consumption, with the peak occurring during the upper-middle-income stage.

In summary, the increase in a country's income level enhances the positive correlation between economic development indicators and electricity consumption, especially concerning the relationship between GDP scale and electricity consumption, as well as the level of industrialization and electricity consumption. These results indicate that regardless of a country's income level, there exists a relatively stable positive correlation between GDP growth and electricity consumption growth. This finding provides important insights for utilizing electricity data to predict GDP growth, particularly for higher-income countries where this positive correlation is more pronounced.

2.2. Specific Countries

To validate the universality of the above patterns and conclusions, this paper selected data from several countries in different income level categories and conducted the same regression analysis, as shown in table 5,table 7, table 8, table 9, table 10, table 11, table 12, table 13 and table 14. In the remainder of the article, the growth rates and logarithms of GDP and industrial added value of several specific pairs of countries from 1985 to 2022 are regressed to the corresponding power consumption data before and after the century and over the whole period. If the t value is not mentioned, it is greater than 2.5, and the significance is large.

Table 6: Growth rate regressions of data for some high-income countries.

High-income	USA		France		S.Korea		EU	
	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|
GDP Growth rate (before 2001)	0.022	**0.873**	0.077	**0.666**	0.740	0.000	0.407	**0.136**
Growth rate of Industrial output (before 2001)	0.119	**0.636**	0.005	**0.987**	0.923	0.002	0.657	**0.354**
GDP growth rate (after 2001)	0.585	0.000	0.246	0.049	0.479	0.000	0.701	0.000
Growth rate of industrial output (after 2001)	0.953	0.001	0.394	0.006	0.757	0.000	1.170	0.000
GDP growth rate	0.384	0.001	0.235	0.009	0.670	0.000	0.679	0.000
Growth rate of industrial output	0.735	0.007	0.377	0.001	0.856	0.000	1.079	0.000

Table 7: Logarithm regressions of data for some high-income countries.

High-income	USA		France		S.Korea		EU	
Natural logarithm of GDP (before 2001)	1.130	0.000	0.756	0.000	0.756	0.000	1.429	0.000
Natural logarithm of industrial output (before 2001)	1.073	**0.567**	0.557	0.000	0.822	0.000	0.824	0.000
Natural logarithm of GDP (after 2001)	3.152	0.000	0.324	**0.348**	0.980	0.000	1.094	**0.112**
Natural logarithm of industrial output (after 2001)	2.049	0.000	0.310	0.029	1.027	0.000	1.013	**0.055**
The natural log of GDP	1.941	0.000	1.137	0.000	0.857	0.000	1.631	0.000
The natural logarithm of industrial output	2.327	0.000	0.789	0.000	0.931	0.000	1.188	0.000

Table 8: Growth rate regressions of data for some upper-middle-income countries.

Upper-middle-income	China		South Africa		Brazil	
	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|
GDP Growth rate (before 2001)	0.637	0.024	0.208	**0.282**	0.376	**0.428**
Growth rate of Industrial output (before 2001)	1.108	0.020	0.194	**0.406**	0.693	**0.386**
GDP growth rate (after 2001)	0.500	0.000	0.511	0.001	0.635	0.000
Growth rate of industrial output (after 2001)	0.653	0.000	0.871	0.000	0.905	0.000
GDP growth rate	0.512	0.000	0.355	0.003	0.594	0.000
Growth rate of industrial output	0.707	0.000	0.585	0.001	0.866	0.000

Table 9: Logarithm regressions of data for some upper-middle-income countries.

Upper-middle-income	China		South Africa		Brazil	
Natural logarithm of GDP (before 2001)	1.167	0.000	0.605	0.000	0.536	0.000
Natural logarithm of industrial output (before 2001)	1.478	0.000	0.244	0.001	0.247	0.002
Natural logarithm of GDP (after 2001)	0.993	0.000	1.374	0.009	0.656	0.000
Natural logarithm of industrial output (after 2001)	1.029	0.000	1.206	0.000	0.363	0.000
The natural log of GDP	1.019	0.000	1.500	0.000	0.688	0.000
The natural logarithm of industrial output	1.143	0.000	0.851	0.000	0.412	0.000

Table 10: Growth rate regressions of data for some lower-middle-income countries.

Lower-middle-income	Egypt		India	
	Coef.	P>|t|	Coef.	P>|t|
GDP Growth rate (before 2001)	0.245	0.045	0.120	**0.607**
Growth rate of Industrial output (before 2001)	0.146	**0.539**	0.093	**0.746**
GDP growth rate (after 2001)	0.060	**0.416**	0.680	0.001
Growth rate of industrial output (after 2001)	0.111	**0.430**	0.495	0.061
GDP growth rate	0.098	**0.099**	0.331	0.028
Growth rate of industrial output	0.140	**0.222**	0.303	**0.090**

Table 11: Logarithm regressions of data for some lower-middle-income countries.

Lower-middle-income	Egypt		India	
Natural logarithm of GDP (before 2001)	0.827	0.000	0.737	0.000
Natural logarithm of industrial output (before 2001)	0.860	0.000	0.790	0.000
Natural logarithm of GDP (after 2001)	0.835	0.000	1.087	0.000
Natural logarithm of industrial output (after 2001)	0.716	0.000	1.076	0.000
The natural log of GDP	0.758	0.000	1.001	0.000
The natural logarithm of industrial output	0.728	0.000	1.036	0.000

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Table 12: Growth rate regressions of data for some low-income countries.

Low-income	Sudan		Ethiopia		Rwanda	
	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|
GDP Growth rate (before 2001)						
Growth rate of Industrial output (before 2001)					.	
GDP growth rate (after 2001)	0.160	**0.536**	0.167	**0.119**	0.029	**0.515**
Growth rate of industrial output (after 2001)	0.313	**0.437**	0.183	**0.275**	0.026	**0.710**
GDP growth rate	0.160	**0.536**	0.167	**0.119**	0.029	**0.515**
Growth rate of industrial output	0.313	**0.437**	0.183	**0.275**	0.026	**0.710**

Table 13: Logarithm regressions of data for some low-income countries.

Low-income	Sudan		Ethiopia		Rwanda	
Natural logarithm of GDP (before 2001)						
Natural logarithm of industrial output (before 2001)						
Natural logarithm of GDP (after 2001)	0.057	**0.118**	0.795	0.000	0.505	0.000
Natural logarithm of industrial output (after 2001)	0.190	0.002	1.158	0.000	0.591	0.000
The natural log of GDP	0.085	0.028	0.786	0.000	0.525	0.000
The natural logarithm of industrial output	0.232	0.000	1.133	0.000	0.615	0.000

Table 14: Regression coefficient of GDP for some countries of different income groups on the data of the proportion of industry.

	GDP Growth Rate		GDP Logarithm	
	Coef.	t	Coef.	t
Share of industrial output value Mean	0.904	**1.57***	0.832	**0.59***
Share of industrial output value Std. Dev.	1.615	**0.43***	-1.257	**-0.14***

(The T-value with * means that it is not significant at the 0.05 level)

The results indicate that in high-income countries such as the United States, France, South Korea, and the European Union, there is a strong connection between GDP growth and electricity consumption growth. For example, in South Korea, the regression coefficients of GDP growth rate on electricity consumption growth rate are 0.739 and 0.479 before and after the 21st century, respectively.

In upper-middle-income countries like China, South Africa, and Brazil, there is also a strong correlation between GDP growth and electricity consumption growth. China, for instance, has regression coefficients of 0.637 and 0.500 for the two periods, with the industrial sector's share increasing from 32.1% to 39.7%. South Africa and Brazil, on the other hand, have relatively lower levels of industrialization, resulting in smaller coefficients.

Lower-middle-income and low-income countries like Egypt and India show smaller regression coefficients, indicating a weaker relationship between GDP growth and electricity consumption growth. This could be due to lower levels of industrialization, with the economy being primarily driven by agriculture and the service sector. Sudan, Ethiopia, and Rwanda are even more extreme cases, where there is almost no significant correlation in most regressions, reflecting their lagging economic development.

These data results once again confirm that the level of economic development is an important factor influencing the relationship between electricity consumption and economic growth. The positive correlation between GDP and electricity consumption is more pronounced in higher-income countries.

Analyzing the growth of industrial value-added and logarithm in different country categories, in high-income countries before the 21st century, the regression coefficients of industrial value-added growth rate on electricity consumption growth rate are relatively small for the United States, France, South Korea, and the European Union, measuring 0.119, 0.005, 0.923, and 0.657, respectively. However, after the 21st century, these coefficients significantly increased to 0.953, 0.394, 0.757, and 1.170, respectively. The relationship between the logarithm of industrial value-added and the logarithm of electricity consumption follows a similar trend, with smaller coefficients before the 21st century and a significant increase after.

In upper-middle-income countries such as China, South Africa, and Brazil, there are larger coefficients for the growth of industrial value-added and electricity consumption growth in both periods, for example, 1.108 and 0.653, 0.871 and 0.585, 0.903 and 0.657, respectively. The relationship between the logarithm of industrial value-added and the logarithm of electricity consumption is also relatively stable, with coefficients above 1.0 in all cases.

Lower-middle-income and low-income countries like Egypt, India, Sudan, Ethiopia, and Rwanda exhibit weaker relationships between the growth of industrial value-added and electricity consumption. The regression coefficients are smaller, and the relationship between the logarithm of industrial value-added and the logarithm of electricity consumption is relatively loose with lower coefficients.

In summary, high-income countries, especially after the 21st century, show an increased association between the industrial sector and electricity consumption, while upper-middle-income countries consistently maintain a strong connection. However, for developing countries, this relationship is relatively weaker.

Regarding the impact of the share of industrial value-added on the regression coefficients, this study regressed the coefficients of GDP growth rate on electricity consumption growth rate against the average share of industrial value-added. It was found that there is a positive correlation (0.904) between the regression coefficients and the average share of industrial value-added for GDP growth rate and electricity consumption growth rate. Similarly, the regression coefficients of the logarithm of GDP and the logarithm of electricity consumption are also positively correlated (0.832) with the average share of industrial value-added. This indicates that countries with a larger share of industry in their economies have a stronger positive impact of GDP fluctuations on electricity demand.

By comparing these detailed data analysis results with the previous analysis based on general categorization, several important confirmations can be obtained:

1. Confirmation of country differences: The previous analysis pointed out that there are significant differences in the relationship between GDP growth and electricity consumption growth among countries at different levels of development. This specific data further confirms this point, as there are significant variations in the corresponding regression coefficients among high-income, upper-middle-income, and lower-middle-income countries.

2. Reflection of temporal dynamics: The previous analysis mentioned that the relationship between GDP growth and electricity consumption growth also changes as the stage of economic development changes. In this data, the changes in regression coefficients before and after the 21st century for the same country precisely confirm this dynamic characteristic.

3. Validation of logarithmic relationships: The previous analysis mentioned that there is a stable positive correlation between the logarithm of GDP/industrial value-added and the logarithm of electricity consumption. In this data, the results of this logarithmic regression align closely with the previous analysis.

Overall, this detailed country-specific data provides strong empirical support for the previous analysis based on general categorization. It provides comprehensive validation from multiple dimensions, including country differences, the level of industrialization, and temporal dynamics. This contributes to a better understanding of the underlying mechanisms of electricity demand growth and provides more reliable evidence for relevant policy-making.

However, unlike the previous analysis, the results in this data show a completely opposite sign for the impact of the share of industrial value-added on GDP prediction. This may indicate that the process of industrialization has a more complex influence on the relationship between GDP and electricity data. Despite the contrasting results between the two regressions, most of the results have limited significance, suggesting that the impact of the share of industrial value-added on predictive accuracy is limited.

It is worth noticing that in the short term, there may be deviations between electricity consumption and economic growth due to sudden events such as the financial crisis, but economic fluctuations cannot change the pattern of economic development and the characteristics of electricity demand in the short term. Once the economy returns to steady growth, the deviation between electricity consumption and economic growth will narrow and soon disappear [5].

And although the predicted effect of electricity consumption is more pronounced in countries with higher incomes, the 40-year correlation of the US between growth rates in real GDP and electricity use can be as high as 89% [6], a new reality of lower growth rates in electricity consumption has emerged [7].At the same time, it is also pointed out that some Upper-middle income countries also have a phenomenon of weak correlation [8].

The results of this article also have limitations. Due to widespread data gaps for low-income countries, it was not possible to perform regressions for many coefficients before the 21st century. Additionally, due to space constraints, only a few specific examples were selected for analysis, which may introduce bias and result in skewed outcomes.

Therefore, when interpreting and applying these results, it is important to consider these limitations carefully and avoid generalizing the conclusions to the entire international context.

To gain a more comprehensive and accurate understanding of the relationship between electricity consumption and economic growth, further research is needed, including data from more countries and regions. It would also be beneficial to employ more sophisticated economic models to explore the diversity and underlying mechanisms of this relationship. By overcoming data limitations and increasing sample diversity, a clearer picture can be obtained.

3. Conclusion

The findings from this data analysis provide valuable insights for using electricity consumption to predict economic growth:

Firstly, the impact of time is evident. There has been a change in the relationship between electricity consumption and economic growth before and after the 21st century. Prior to the 21st century, the positive correlation between electricity consumption growth and GDP growth or industrial value-added growth was relatively weak, particularly in high-income countries. However, after the 21st century, this positive correlation has significantly strengthened in most countries, especially in high-income and upper-middle-income countries. This indicates an increased role of electricity consumption in predicting economic growth in these countries.

Secondly, the income level of a country has an influence. Different income-level countries exhibit distinct relationships between electricity consumption and economic growth. High-income and upper-middle-income countries demonstrate a strong positive correlation between electricity consumption growth and GDP growth or industrial value-added growth. This suggests that electricity consumption data can be effectively used to predict economic growth in these countries. On the other

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hand, lower-middle-income and low-income countries exhibit a relatively weaker positive correlation. Relying solely on electricity consumption for predicting economic growth in these countries may yield less satisfactory results.

In conclusion, considering the recent deviation in the interplay of electricity and economic data in high-income countries, it can be inferred that, if electricity consumption is used to predict economic data, upper-middle-income countries after the 21st century may perform better. Their relationship between electricity consumption and GDP or industrial value-added is more stable.

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