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The Dynamics of Energy Use Economic Growth and Financial Development in India and China

Hrushikesh Nur[a]
Akh Kumar[b]

Abstract
This study empirically examines the relationships among energy use, economic growth, and financial development in India and China, utilizing annual data from 1971 to 2020. Employing the auto regressive distributed lag approach to cointegration, the study provides nuanced insights into how these factors interact within the two rapidly developing economies. The results reveal that energy consumption in both India and China is positively influenced by the proportion of the urban population, indicating that as urbanization increases, so does the demand for energy. This can be attributed to the higher energy requirements associated with urban living, such as increased use of electricity, transportation, and industrial activities. Conversely, the study finds that financial development, economic growth, and the proportion of industrial output negatively influence energy consumption in both countries. This suggests that as these economies grow and develop financially, they become more efficient in their energy use, possibly due to advancements in technology and more stringent energy policies. The negative impact of industrial output on energy consumption could be indicative of a shift towards less energy-intensive industries or improvements in industrial energy efficiency. The study further explores the impact of these variables on economic growth and finds contrasting results for India and China. In India, urbanization is found to adversely influence economic growth. This could be due to the challenges associated with rapid urbanization, such as inadequate infrastructure, congestion, and environmental degradation. However, energy use positively influences economic growth, underscoring the importance of energy availability for sustaining economic activities and development. In China, the findings are quite different. While financial development, energy use, and industrial output are found to adversely impact economic growth, urbanization positively influences it. This is contrary to the common belief that China's industrial sector is the primary driver of its economic success. The positive impact of urbanization on economic growth in China suggests that urbanization has been well-managed, contributing to economic development through improved infrastructure, better access to services, and enhanced productivity. These findings have significant policy implications for both countries. In India, there is a need to address the negative impacts of urbanization on economic growth by investing in sustainable urban planning and infrastructure development. Policies that promote energy efficiency and support the growth of the energy sector can also help to harness the positive impact of energy use on economic growth. For China, the results suggest that while urbanization continues to drive economic growth, there is a need to balance this with efforts to mitigate the negative impacts of financial development, energy use, and industrial output on the economy. This could involve promoting cleaner technologies, enhancing energy efficiency, and implementing policies that support sustainable industrial practices.
Keywords: Energy Consumption, Economic Growth, Financial Development
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1. INTRODUCTION

The study delves into the intricate relationships between energy consumption and economic growth in two of the world's largest and fastest-growing economies, India and China. As these economies continue to expand due to industrialization, urbanization, and other economic activities, their demand for energy also escalates significantly, making them highly reliant on energy resources. Table 1 illustrates the substantial shares of energy consumption attributed to India and China on a global scale, underscoring their significance in the global energy landscape. However, the study aims to unravel the causal links between energy consumption and economic growth in these nations. Specifically, it seeks to ascertain whether economic growth drives increased energy consumption or if the causality operates in the opposite direction. Moreover, recognizing that financial development can influence both economic growth and energy consumption, the study delves into the role of financial development in shaping patterns of energy consumption and economic growth. By examining these multifaceted relationships, the study endeavors to provide insights into the complex dynamics between energy, finance, and economic development in India and China. It introduces the role of financial development, highlighting that without endogenizing financial development as a variable in the energy demand model, there is a risk of underestimating the true

[a] Amrita School of Business, Amrita Vishwa Vidyapeetham University, India
[b] Amrita School of Business, Amrita Vishwa Vidyapeetham University, India

energy demand for emerging economies (Sadorsky, 2003; Islam et al., 2013). This underscores the intricate relationship between financial development and energy consumption, particularly in emerging markets such as Malaysia.

Research by Islam et al. (2013) provides valuable insights into the nexus between financial development and energy consumption in Malaysia, employing a multivariate time series analysis to explore the dynamic interactions between these variables. Their findings shed light on the importance of considering financial factors in energy demand modeling, emphasizing the need for a comprehensive understanding of the economic and financial landscape to accurately forecast energy demand trends. Additionally, the work of Sadorsky (2003) and other scholars has contributed to understanding the causal relationship between energy consumption and GDP in both G-7 countries and emerging markets. Their studies highlight the complex interplay between economic development, financial dynamics, and energy consumption patterns, emphasizing the significance of incorporating financial development as a key variable in energy demand models to enhance their predictive accuracy and policy relevance. Understanding the determinants of energy demand is pivotal for shaping sustainable energy policies, particularly in emerging countries where economic growth is rapidly evolving. As major emerging economies intensify their competition for economic prosperity, the relationship between energy use and economic growth becomes increasingly significant. The projected deepening of this relationship underscores the importance of comprehending the factors driving energy consumption. Energy serves as a critical input in the production process across various sectors, making it indispensable for economic activities. The rapid growth experienced by many emerging economies has led to a surge in energy demand, highlighting the necessity of understanding the drivers of this demand. Despite the global economic downturn in 2009, it is noteworthy that China and India, two major energy-consuming nations in Asia, exhibited resilience to its effects. This resilience underscores the robustness of their energy sectors and their enduring influence on global energy demand dynamics. By delving into the determinants of energy consumption, policymakers can gain valuable insights to formulate effective strategies for ensuring sustainable energy use and fostering economic development in emerging economies.

The projections from the International Energy Agency paint a vivid picture of the global energy landscape, with developing economies poised to drive a significant portion of the increase in primary energy demand. Over the period from 2005 to 2030, developing economies are expected to contribute a substantial 74% of the global demand growth, with China and India playing a particularly prominent role. China and India are forecasted to collectively account for over 53% of the global increase in primary energy demand, with average annual growth rates of 3.2% and 3.6%, respectively. These figures underscore the immense energy needs of these rapidly growing economies, fueled by ongoing industrialization and urbanization processes. The implications of these projections are far-reaching, presenting both challenges and opportunities for policymakers and energy stakeholders worldwide. Managing the energy dynamics of China and India effectively will be crucial for steering the global energy markets and addressing critical environmental and sustainability issues on a global scale. It calls for concerted efforts to promote energy efficiency, invest in renewable energy sources, and adopt innovative technologies to ensure a sustainable and resilient energy future.

Table 1: Share of global energy consumption

Country/Year	1965	1985	2011
China	129.3 (3.4%)	522.2 (7.2%)	2613.2 (21.3%)
India	52.7 (1.4%)	132.7 (1.8%)	559.1 (4.6%)
OECD Countries	2625.1 (70%)	4188.5 (58.5%)	5527.7 (45%)
Total World	3750.0 (100.0)	7161.3 (100.0)	12274.6 (100.0)

The relationship between energy use and economic development is deeply intertwined, and it evolves across different stages of an economy's growth trajectory. Emerging economies, characterized by rapid industrialization and urbanization, often experience a surge in energy demand as they strive to fuel their growth and development. At the initial stages of development, energy consumption tends to be relatively low as economies primarily rely on traditional and less energy-intensive forms of production. However, as industrialization gains momentum and urban centers expand, the demand for energy escalates significantly. Energy becomes a critical input for powering industries, infrastructure development, transportation networks, and the provision of essential services. Industrialization, in particular, drives up energy demand as manufacturing processes become more mechanized and energy-intensive. Urbanization also plays a crucial role, as cities become hubs of economic activity, consumption, and population growth, leading to increased energy requirements for transportation, housing, and commercial activities. The link between energy use and economic growth underscores the importance of ensuring access to reliable and affordable energy sources to support sustainable development. As emerging economies continue to evolve, policymakers face the challenge of balancing energy security, environmental sustainability, and economic growth objectives. By promoting energy efficiency, diversifying energy sources, and investing in renewable energy infrastructure, countries can mitigate the environmental impact of energy consumption while supporting their development aspirations.

There can be a two-way causality between energy use and economic growth. Financial development has been directly linked to economic growth in numerous studies (McKinnon, 1973; Shaw, 1973; King & Levine, 1993; Warman &

Thirlwall, 1994; Pill, 1997). Similarly, both theoretical frameworks and empirical evidence suggest a two-way causality between financial development and economic growth, particularly in developing economies, where efficient allocation of financial resources plays a crucial role in driving growth. Since availing financial resources involves costs, financial development occurs when resources are efficiently allocated in a liberalized financial system. This implies that since economic growth is directly related to both financial development and energy use, financial development should also spur energy use. However, this relationship may reverse if economies make conscious efforts to reduce energy consumption through efficient use and tapping energy from the most efficient sources. Some argue that the existence of a well-developed financial market encourages the inflow of foreign direct investment (FDI), which brings superior technology and managerial skills. This enables firms to use energy more efficiently in the production process, thereby reducing energy consumption (Sadorsky, 2010; Islam et al., 2013). The study delves into the intricate relationship between financial development, entrepreneurial activities, and industrial growth, all of which can exert significant influence on energy demand within an economy. The dynamics of this relationship are complex and multifaceted, with financial development potentially catalyzing entrepreneurial ventures and industrial expansion, thereby leading to an increase in energy consumption. However, the direction and magnitude of this relationship can vary depending on numerous factors inherent to each country's context. Empirical investigation serves as a crucial tool for unraveling the intricacies of this relationship and elucidating its implications for both energy policy and economic development.

Through this study, we aim to contribute to the ongoing policy discourse by empirically analyzing the determinants of energy demand in two major energy-consuming developing economies. The structure of our study is meticulously designed to facilitate a comprehensive analysis of the factors influencing energy demand. In Section 2, we undertake a thorough review of the relevant literature, synthesizing previous research findings and theoretical frameworks pertaining to energy consumption and economic development. This review provides a nuanced understanding of the existing knowledge landscape and informs our analytical approach. Section 3 delineates the model employed in our study, elucidating the key variables and theoretical underpinnings that guide our analysis. By clearly specifying the model framework, we ensure transparency and coherence in our research methodology. The subsequent section, Section 4, offers insights into the data sources and methodology utilized for empirical analysis. Detailed information regarding the data collection process and analytical techniques employed enhances the robustness and reliability of our findings. In Section 5, we delve into the econometric techniques employed to analyze the data and estimate the model parameters. This section elucidates the methodological rigor underpinning our empirical analysis, thereby enhancing the credibility of our research outcomes. Section 6 presents the empirical results derived from our analysis, offering valuable insights into the determinants of energy demand and their implications for energy policy and economic development. This section serves as the focal point of our study, providing actionable insights for policymakers and stakeholders. Finally, in Section 7, we draw conclusive remarks and formulate policy recommendations based on the findings of our study. By synthesizing our empirical findings with theoretical insights, we offer pragmatic recommendations to foster efficient energy use and sustainable development strategies in the context of emerging economies.

2. LITERATURE REVIEW

Research conducted by Akarca and Long (1980), Yu and Hwang (1984), Yu and Choi (1985), and Yu and Jin (1992) has provided insights into the intricate relationship between total energy consumption and income in the United States. Surprisingly, these studies found no evidence of a causal relationship between energy consumption and income. This suggests that while economic growth may drive energy consumption, the reverse relationship, where energy consumption fuels economic growth, may not hold true in the context of the United States. In contrast, Kraft and Kraft (1978) and Abosedra and Baghestani (1989) observed a causal link from Gross National Product (GNP) growth to energy consumption. This implies that as the economy grows, there is an increasing demand for energy resources to sustain economic activities and meet the needs of a growing population. These findings underscore the complexity of the relationship between energy consumption and economic growth, which can be influenced by various factors such as technological advancements, energy efficiency measures, and shifts in industrial structure. Moreover, the absence of a clear causal relationship between energy consumption and income in some studies highlights the need for further research to better understand the underlying dynamics and implications for energy policy and sustainable development. By deepening our understanding of the interplay between energy consumption and economic growth, policymakers can develop more effective strategies to promote energy security, enhance resource efficiency, and foster sustainable economic development. Continued research in this area will be essential for addressing the challenges of energy transition and ensuring a resilient and sustainable energy future for all.

Research by Soytas and Sari (2003) revealed that causality runs from GDP to energy consumption for Italy and Korea out of the sixteen countries they studied. Similarly, Masih and Masih (1997) found similar evidence for both Taiwan and Korea, while Yang (2000) confirmed a bi-directional causality for Taiwan. Ebohon (1996) demonstrated a simultaneous causal relationship for both Nigeria and Tanzania. The findings of these studies underscore the nuanced nature of the relationship between energy consumption and economic growth, which can vary significantly across different countries and regions. As energy plays a key role in economic development, the general implication is that unless energy supply constraints are eased, economic development may remain elusive. Horn (1999) observed that energy intensity is extremely high for Ukraine, even in comparison with Russia and other transition economies. This was attributed to technical inefficiencies, structural factors (such as a high share of basic industry), and persistent economic crises. Masih and Masih (1996) examined the relationship for six Asian economies (India, Pakistan, Malaysia, Singapore, Indonesia, and the Philippines). They found that energy consumption was neutral to income in Malaysia, Singapore, and the Philippines. Unidirectional causality existed from energy consumption to GNP for India, while the reverse causality existed for Indonesia, and a mutual causality existed for Pakistan. The results of Soytas and Sari (2003) were similar to those of Erol and Yu (1987) for Turkey, along with similarity in results for France, Germany, and Japan. The unidirectional causality from energy consumption to GDP growth for Turkey indicated that, in the long run, decreasing energy consumption may hinder economic growth. Sari and Soytas (2004), utilizing the recently developed generalized forecast error variance decomposition of Koop et al. (1996) and Pesaran and Shin (1998), found that the growth of waste had the largest impact on the variation of national income growth, followed by the growth of oil. Ediger and Huvaz (2006) observed a linear relationship between energy use and GDP for Turkey during the period of 1980-2000. Their analysis led them to conclude that if the causality from energy consumption to GDP persists into the future and the rates of energy consumption and GDP maintain their past trends, any decrease in energy consumption is expected to slow down economic growth.

In contrast, Erol and Yu (1987) observed a bi-directional relationship for Italy out of six industrialized countries studied. Subsequently, Wolde-Rufael (2005) found the existence of a long-term relationship between energy consumption and income for eight countries and causality for 10 out of 19 African countries studied. Further, Lee (2006), studying 11 major industrialized countries, found that while energy consumption and income are neutral to each other for the UK, Germany, and Sweden, there is bi-directional causality in the USA and unidirectional causality from energy consumption to GDP in Canada, Belgium, the Netherlands, and Switzerland. They suggested that energy conservation would hinder economic growth. Furthermore, observing the unidirectional causal relationship in the reverse way for France, Italy, and Japan, Lee implied that in these countries, energy conservation may be viable without affecting growth. Ajmi et al. (2013) examined the causal links for G7 countries from 1960 to 2010. Their empirical test yielded mixed results. These diverse findings highlight the complex and context-dependent nature of the relationship between energy consumption and economic growth. Understanding these dynamics is crucial for informing energy policies that promote sustainable development while ensuring economic prosperity.

Since electricity is considered as the most efficient sources of energy, a significant proportion of recent literature have devoted in uncovering the linkage between the electricity consumption and economic growth. Mozumder and Marathe (2007) found a unidirectional causality from per capita GDP to per capita electricity consumption for Bangladesh. Ozturk (2010) provided an extensive survey of recent contributions in the literature on the nexus between energy consumption–economic growth and electricity consumption–economic growth and concluded that there was no consensus on the existence or the direction of causality. Using panel data for 22 emerging economies during 1990-2006, Sadorsky (2010) found a positive relationship between financial development and energy consumption. Employing ARDL and Granger causality tests for Tunisia, Shahbaz and Lean (2012) investigated the impact of financial development on energy consumption. They found a long-run relationship and a bi-directional causality between financial development and energy consumption, suggesting that a well-established developed financial system increases energy consumption. There are also some recent literatures which relate energy use with economic growth, financial development, and urbanization. Islam et al. (2013) investigated the long-run relationship between energy consumption, financial development, economic growth, and population in Malaysia. They found that financial development, growth, and population influence energy consumption.

These studies underscore the complexity of the relationship between energy consumption and various economic factors, highlighting the need for further research to better understand the dynamics and implications of this nexus.

Paul and Bhattacharya (2004) examined the relationship between energy consumption and economic growth in India from 1950 to 1996. They found that economic growth leads to energy consumption in the long run, but energy consumption leads to economic growth in the short run. Ghosh (2006) studied the relationship between petroleum product consumption and economic growth in India from 1970 to 2002 and identified a long-run equilibrium relationship between the two variables.

In a more recent study by Abbas and Choudhry (2013), the causality between electricity consumption and economic growth in India and Pakistan was investigated for the period 1972-2008. The empirical findings revealed a bi-directional causality between agricultural electricity consumption and agricultural GDP in India. Conversely, for Pakistan, the causality was found to run from agricultural GDP to agricultural electricity consumption.

At the aggregate level, the conservation hypothesis, where economic growth drives electricity consumption, was supported for India, while the feedback hypothesis, indicating a bi-directional relationship between electricity consumption and economic growth, was supported for Pakistan. These findings provide valuable insights into the complex relationship between energy consumption and economic growth, particularly in the context of agriculture, in these two densely populated South Asian countries. The existing literature reveals a notable disparity in the extent of systematic studies conducted on the relationship between energy use and economic growth in India compared to China. While there is a wealth of research available on this topic for China, the literature pertaining to India is relatively limited in scope and depth. Furthermore, empirical investigations that specifically examine the interplay between financial sector development, economic growth, and energy use remain scarce for both countries.

This research gap underscores the need for comprehensive and rigorous empirical studies that explore the intricate dynamics between financial sector development, economic growth, and energy consumption in the context of India and China. By addressing this knowledge gap, researchers can contribute valuable insights to the ongoing discourse on energy policy and sustainable development in these emerging economies. Moreover, bridging this gap in the literature can inform policymakers and stakeholders about the complex interdependencies among financial development, economic growth, and energy demand, thereby facilitating evidence-based decision-making and the formulation of effective policy interventions. Moving forward, concerted efforts should be made to conduct systematic studies that shed light on these critical issues and provide actionable insights for promoting energy efficiency and sustainable development in India and China. Mallick (2009) conducted an important study in India, examining the linkage between energy consumption and economic growth. This study departed from conventional approaches by exploring various forms of energy consumption and their relationship with economic growth. By doing so, Mallick aimed to formulate policy strategies tailored to different sources of energy. However, there is still a gap in the literature regarding comparative studies that examine these key variables from a comparative perspective in two populous countries that are closely located in Asia. Such studies could provide valuable insights into the similarities and differences in the relationships between energy consumption and economic growth in different regional contexts.

The study strongly advocates for reducing crude oil and natural gas consumption, particularly in sectors that do not directly contribute to production or capital formation. While this recommendation aligns with existing literature, the present study seeks to enrich our understanding by incorporating additional factors such as financial development and urbanization. Surprisingly, these variables have been largely overlooked in previous research focusing on the energy dynamics of the world's two major energy-consuming economies. By employing a more robust statistical technique, this study aims to provide a comprehensive analysis of the complex relationship between energy consumption, financial development, and urbanization in India and China. By considering these influential factors, the research endeavors to offer insights that can inform more targeted and effective energy policies and strategies for mitigating energy consumption in sectors with lower productivity or capital accumulation. This approach represents a significant advancement in the field, as it enables a more nuanced understanding of the underlying drivers of energy demand and consumption patterns in these two key economies. Ultimately, the findings of this study have the potential to guide policymakers and stakeholders in developing evidence-based interventions to promote sustainable energy use and facilitate the transition towards a more environmentally sustainable and economically resilient future.

3. THE MODEL

Drawing from the previous literature (Shahbaz and Lean 2012 & Islam et al., 2013) and considering our objectives of the study, the following model expresses the relationship between energy consumption, economic growth, financial development and the proportion of urban population in total population in a partial model.

EGUSE=F(IPOPNT, DCGDP, GDPGR, INDGDP)

here, EGUSE - Total quantum of energy used, UPOPNT- Urban population as a proportion to total population, DCGDP- domestic commercial bank credit to the private sector as a proportion to GDP, GDPGR - growth rate of GDP, INDGDP- Industrial output as a proportion to total output. The proportion of urban population is expected to exert a positive impact on energy consumption. The domestic bank credit to GDP may have either positive or negative impact on energy use. Growth rate of GDP and proportion of industrial output in the total are supposed to have positive impacts. The study covers the annual data from 1971-2020. The data relating to the total energy use (EGUSE), proportion of urban population in total population (UPOPNT), domestic credit as a proportion of GDP (DCGDP), Real GDP growth rate (GDPgr), industrial output as a proportion of GDP (INDGDP) used in the study are all drawn from World Development Indicators of the World Bank (WB). Energy use reflects the total energy consumption annually in kg of oil equivalents. Domestic bank credit to private sector as a share of GDP measures the financial development. Proportion of urban population to total population reflects the degree of concentration of population and the effects of urbanization.

4. ECONOMETRIC METHODOLOGY

The study utilizes the Autoregressive Distributed Lag (ARDL) approach to cointegration, as advocated by Pesaran, Shin, and Smith (2001), which is considered a suitable strategy for uncovering the relationship outlined in equation (1). This approach offers several advantages over traditional cointegration methods proposed by Engel and Granger (1987) and Johansen and Juselius (1992). The ARDL approach is particularly favored for its ability to handle small sample sizes, mixed orders of integration, and endogenous regressors efficiently. It also provides robust results and accommodates both short-run and long-run dynamics in the relationship between energy consumption and economic growth. The utilization of the ARDL approach to cointegration methodology addresses several key challenges inherent in conventional techniques, thereby enhancing the robustness and reliability of the analysis. One significant advantage of the ARDL approach is its ability to accommodate small sample properties and mitigate simultaneity bias among variables. Unlike conventional cointegration techniques, which require all variables to be non-stationary at levels and integrated of the same order, the ARDL approach remains applicable regardless of the order of integration of regressors, whether they are I(0), I(1), or a mixture of both. This flexibility is particularly valuable given the uncertainties associated with checking the time series properties of variables, which may lead to biased outcomes when selecting unit root tests. By allowing for varying orders of integration, the ARDL model offers a more robust framework for capturing the underlying dynamics of the data generating process. Additionally, the ARDL model facilitates the selection of an appropriate number of lags to ensure an accurate representation of the data, thus enhancing the precision of parameter estimation. Furthermore, the ARDL approach enables the derivation of a dynamic error correction model (ECM), providing policymakers with valuable insights into the short-run adjustment process. This feature is particularly useful for understanding the dynamics of economic relationships and informing policy interventions aimed at achieving long-term stability and sustainability. Empirical studies have demonstrated the superior properties of ARDL-based estimators, showing them to be "super-consistent" and capable of yielding valid inferences on long-run parameters using standard asymptotic theory. Additionally, appropriate modifications to the orders of the ARDL model can effectively address residual serial correlation and endogenous regressor issues, further enhancing the reliability of the estimation results.

5. ESTIMATED OUTCOMES

Before proceeding with the estimation of the energy consumption model using the ARDL approach to cointegration, it is essential to test the nature of the variables included in the analysis. To this end, we employ the Ng-Perron (2001) unit root test, chosen for its reliability and consistency in yielding accurate results, especially in small samples. The unit root test results presented in Table 2 for India indicate that variables such as EGUSE (energy use), UPONT (proportion of urban population to total), and GDPgr (GDP growth rate) are stationary in levels. On the other hand, variables DCGDP (financial development indicator) and INDGDP (industrial output) are non-stationary but become stationary in first differences. This suggests that our model comprises a mixture of I(1) and I(0) variables, reflecting the complex dynamics of the Indian economy. Similarly, Table 3 displays the unit root test results for China, which largely mirror those for India. In the case of China, the financial development indicator (DCGDP) and industrial output (INDGDP) are found to be difference stationary, while energy use, GDP growth rate, and the proportion of urban population to total are stationary in levels. Once again, this indicates a mix of integrated variables within the model. The presence of mixed integrated variables in both the Indian and Chinese contexts justifies the suitability of employing the ARDL approach to cointegration for our analysis. This approach allows for the estimation of models with variables of different orders of integration, thereby accommodating the diverse nature of the economic data and enhancing the robustness of our empirical analysis.

Table 1: **Unit root test results (Ng-Perron) for India**

Variables	MZa	MZt	MSB	MPT
EGUSE	-19.91*	-2.90	0.14	2.1
UPOPNT	-9.22**	-1.92	0.20	3.42
DCGDP	3.46	2.93	0.84	75.95
GDPgr	-18.18*	-2.95	0.16	1.57
INDGDP	-0.69	-0.37	0.54	18.22
ΔDCGDP	-6.87**	-1.78	0.25	3.81
ΔINDGDP	-18.09*	-2.96	0.163	1.52

Table 1 presents the results of the unit root test using the Ng-Perron method for various variables in the context of India. The test statistics include MZa (Zivot-Andrews), MZt (Zivot-Andrews with a time trend), MSB (Modified Standard Bartlett Kernel), and MPT (Modified Park-Test). For the variable EGUSE, which likely represents energy usage, the MZa statistic indicates strong evidence of stationarity with a value of -19.91*, significant at the 1% level. However, the MZt statistic is -2.90, suggesting stationarity only at the 5% level. UPOPNT, possibly representing population growth, shows stationarity with a MZa statistic of -9.22**, significant at the 5% level. DCGDP, which may refer to changes in GDP, exhibits stationarity with a MZa statistic of 3.46, but the MZt statistic of 2.93 is insufficient to confirm stationarity. Similarly, GDPgr, likely indicating GDP growth, demonstrates stationarity with a MZa statistic of -18.18*, significant at the 1% level, while the MZt statistic is -2.95, significant at the 5% level. INDGDP, representing industrial GDP, does not show strong evidence of stationarity, with MZa and MZt statistics of -0.69 and -0.37, respectively. ΔDCGDP, representing the first difference of GDP changes, shows stationarity with a MZa statistic of -6.87**, significant at the 5% level. ΔINDGDP, the first difference of industrial GDP, exhibits stationarity with a MZa statistic of -18.09*, significant at the 1% level. Overall, the unit root test results suggest mixed evidence of stationarity among the variables tested, with some indicating stationarity and others showing evidence to the contrary.

Table 2 summarizes the results of the unit root test conducted using the Ng-Perron method for various variables in the context of China. The test statistics include MZa (Zivot-Andrews), MZt (Zivot-Andrews with a time trend), MSB (Modified Standard Bartlett Kernel), and MPT (Modified Park-Test). For the variable EGUSE, likely representing energy usage, the MZa statistic is -42.94*, indicating strong evidence of stationarity at the 1% significance level. The MZt statistic is -4.43, also significant at the 1% level. UPOPNT, possibly indicating population growth, shows stationarity with a MZa statistic of -23.64*, significant at the 1% level, and a MZt statistic of -3.30, significant at the 5% level. DCGDP, representing changes in GDP, does not exhibit strong evidence of stationarity, with MZa and MZt statistics of -11.99 and -2.45, respectively. Similarly, GDPgr, which may indicate GDP growth, does not demonstrate clear stationarity, with MZa and MZt statistics of

-11.20* and -2.37, respectively. INDGDP, likely representing industrial GDP, shows evidence of stationarity, with MZa and MZt statistics of -9.25** and -2.15, respectively, both significant at the 5% level. The first difference of GDP changes, ΔDCGDP, exhibits stationarity with a MZa statistic of -18.00*, significant at the 1% level. ΔINDGDP, the first difference of industrial GDP, also shows stationarity, with a MZa statistic of -17.60*, significant at the 1% level. Overall, the unit root test results suggest mixed evidence of stationarity among the variables tested for China, with some variables showing clear stationarity and others indicating less clear patterns.

Table 2: Unit root test results (Ng-Perron) for China

Variables	MZa	MZt	MSB	MPT
EGUSE	-42.94*	-4.43	0.10	3.12
UPOPNT	-23.64*	-3.30	0.14	4.64
DCGDP	-11.99	-2.45	0.20	7.60
GDPgr	-11.20*	-2.37	0.21	8.14
INDGDP	-9.25**	-2.15	0.23	9.85
ΔDCGDP	-18.00*	-2.56	0.15	7.23
ΔINDGDP	-17.60*	-2.97	0.17	5.19

Table 3: Cointegration results for India

Model for estimation	Lag length	F-Statistics	1% range CV	5% range CV
F_{EGUSE} (EGUSE, UPOPNT, DCGDP, GDPGR, INDGDP)	3	4.73*	3.81 - 5.12	2.85 - 3.04
F_{GDPGR} (GDPGR, UPOPNT, DCGDP, EGUSE, INDGDP)	2	9.11*	3.81 - 5.12	2.85 - 3.04

The cointegration analysis results presented in Table 3 for India indicate the presence of cointegration for both the energy consumption model and the GDP growth model. The null hypothesis of no cointegration cannot be rejected at the 5% and 1% significance levels, respectively. This conclusion is supported by the F-statistics, which surpass the upper band of the critical values (CVs) at these significance levels. On the other hand, the results for China, as shown in Table 4, yield an inconclusive decision regarding cointegration for the energy consumption model. The computed F-statistic falls between the two critical bands at the 10% significance level, making it difficult to determine the presence of cointegration. However, for the GDP growth model, the F-statistic exceeds the upper critical band at the 1% significance level, providing evidence of cointegration in this case. Despite the inconclusive decision regarding cointegration for the energy consumption equation in China, we proceed with the assumption of its presence. This decision is based on the F-statistic exceeding the lower band of the critical value at the 10% significance level. Consequently, we proceed to solve the model to obtain the long-run and short-run parameters, similar to the approach adopted for the other models considered in the analysis.

Table 4: Cointegration results for China

Model for estimation	Lag length	F-Statistics	5% range CV	10% range CV
F_{EGUSE} (EGUSE, UPOPNT, DCGDP, GDPGR, INDGDP	3	2.50	2.85 - 3.04	2.42 – 3.57
F_{GDPGR} (GDPGR, UPOPNT, DCGDP, EGUSE, INDGDP	3	5.80*	2.85 - 3.04	2.42 – 3.57

The cointegration results for China, as presented in Table 4, are based on two different models for estimation. For the model involving FEGUSE (EGUSE, UPOPNT, DCGDP, GDPGR, INDGDP), a lag length of 3 is employed. The computed F-statistic is 2.50, and it falls within the range of critical values (CV) at the 5% level, which is between 2.85 and 3.04. Similarly, at the 10% significance level, the F-statistic lies within the range of 2.42 to 3.57.

In the case of the FGDPGR model (GDPGR, UPOPNT, DCGDP, EGUSE, INDGDP), also using a lag length of 3, the computed F-statistic is 5.80. This exceeds the critical values at the 5% significance level, indicated by the asterisk (*), suggesting significance at the 1% level. The 5% and 10% range CVs are the same as those for the previous model. Overall, the results indicate cointegration in both models, with the FGDPGR model showing stronger evidence of cointegration, as indicated by the higher F-statistic and significance level.

The long-run estimates derived from the ARDL approach for the energy consumption model in India, as depicted in Table 5, reveal several noteworthy findings. Firstly, it's observed that the proportion of urban population has a significant and positive impact on energy use, implying that urbanization leads to increased energy consumption. Surprisingly, factors like industrial output as a percentage of GDP, private sector bank credit as a percentage of GDP, and GDP growth rate exhibit negative influences on energy consumption. This suggests that higher industrial output and GDP growth rates are associated with reduced energy consumption, contrary to previous studies' findings. Analyzing the short-run estimates from the ECM equation, as presented in Table 6, reveals further insights. The negative sign of the ECM coefficient indicates that deviations from the long-run equilibrium are corrected at a rate of approximately 0.31 units annually. However, it's noteworthy that the signs of the parameters for urban population proportion, GDP growth rate, and industrial output proportion change in the short-run compared to their long-run effects, indicating that these variables influence energy demand in opposite directions in the short-run. On the other hand, examining the long-run estimates for the energy consumption model in China, as shown in Table 7, reveals similar findings to those observed for India. However, there are differences in the magnitude of the parameters, suggesting variations in the factors influencing energy consumption between the two countries.

Table 5: Long-run estimates of energy consumption from ARDL model (India)

Dependent Variable:EGUSE

Regressor	Coefficient	T-Ratio[Prob]
UPOPNT	55114.7	21.51[.000]
DCGDP	-5759.6	-3.36 [.003]
GDPGR	-2197.6	-1.99 [.058]
INDGDP	-12969.0	-3.22 [.004]
C	-740861.3	-6.75 [.000]

Table 6: Short-run estimates of energy consumption from ARDL model (India)

Dependent variable: Deguse

Regressor	Coefficient	T-Ratio[Prob]
dEGUSE1	-1.038	-4.23[.00]
dUPOPNT	-78754.2	-1.99[.05]
dDCGDP	2.82	.004[.99]
dDCGDP1	-1668.9	-1.98[.05]
dDCGDP2	-2235.8	-2.62[.01]
dGDPGR	689.61	2.29[.03]
dINDGDP	4069.8	2.57[.01]
dC	232489.0	3.41[.00]
ecm(-1)	-.31	4.32[.00]
R-Bar-Squared		.80
DW-statistic : 2.13		

The short-run estimates of energy consumption from the ARDL model for India, as presented in Table 6. Dependent variable: Deguse The coefficient for dEGUSE1 is -1.038 with a t-ratio of -4.23 (significant at $p < 0.00$), indicating that a one-unit increase in the first lag of energy use leads to a decrease in energy consumption by approximately 1.038 units in the short run. Similarly, the coefficient for dUPOPNT is -78754.2 with a t-ratio of -1.99 (significant at $p < 0.05$), suggesting that a one-unit increase in the first difference of the proportion of urban population to total population leads to a decrease in energy consumption by approximately 78754.2 units in the short run. On the other hand, the coefficients for dDCGDP, dDCGDP1, and dDCGDP2 are 2.82, -1668.9, and -2235.8, respectively. While the coefficient for dDCGDP is not significant ($p > 0.99$), indicating no significant impact on energy consumption, the coefficients for dDCGDP1 and dDCGDP2 are significant at $p < 0.05$ and $p < 0.01$, respectively. This suggests that changes in the ratio of industrial output to GDP have a significant influence on energy consumption, with lagged effects observed in the short run. Furthermore, the coefficients for dGDPGR and dINDGDP are 689.61 and 4069.8, respectively, both significant at $p < 0.05$ and $p < 0.01$, indicating that changes in GDP growth rate and the proportion of industrial output to GDP lead to significant adjustments in energy consumption in the short run. The coefficient for the constant term (dC) is 232489.0 with a t-ratio of 3.41 (significant at $p < 0.00$), implying that changes in the constant term have a significant impact on energy consumption in the short run. Additionally, the error correction term (ecm(-1)) has a coefficient of -0.31 with a t-ratio of 4.32 (significant at $p < 0.00$), indicating that deviations from the long-run equilibrium are corrected by approximately 0.31 units annually in the short run. Finally, the adjusted R-squared value (R-Bar-Squared) is 0.80, indicating that approximately 80% of the variation in energy consumption is explained by the independent variables in the model. The Durbin-Watson statistic is 2.13, suggesting no significant autocorrelation in the model residuals.

The long-run estimates of energy consumption from the ARDL model for China, as presented in Table 7. Dependent variable: EGUSE The coefficient for UPOPNT is 92103.8 with a t-ratio of 9.16 (significant at $p < 0.00$), indicating that a one-unit increase in the proportion of urban population to total population leads to an increase in energy consumption by approximately 92103.8 units in the long run. Similarly, the coefficient for DCGDP is -23333.3 with a t-ratio of -5.33 (significant at $p < 0.00$), suggesting that a one-unit increase in the first difference of the ratio of industrial output to GDP leads to a decrease in energy consumption by approximately 23333.3 units in the long run. The coefficient for GDPGR is -

21697.9 with a t-ratio of -2.43 (significant at $p < 0.02$), indicating that a one-unit increase in GDP growth rate leads to a decrease in energy consumption by approximately 21697.9 units in the long run. Similarly, the coefficient for INDGDP is -33234.5 with a t-ratio of -2.54 (significant at $p < 0.02$), suggesting that a one-unit increase in the proportion of industrial output to GDP leads to a decrease in energy consumption by approximately 33234.5 units in the long run. Finally, the coefficient for the constant term (C) is 1415088 with a t-ratio of 2.26 (significant at $p < 0.03$), implying that changes in the constant term have a significant impact on energy consumption in the long run.

Table 7: Long-run estimates of energy consumption from ARDL model (China)

Dependent variable: EGUSE

Regressors	Coefficient	T-Ratio[Prob]
UPOPNT	92103.8	9.16[.00]
DCGDP	-23333.3	-5.33[.00]
GDPGR	-21697.9	-2.43[.02]
INDGDP	-33234.5	-2.54[.02]
C	1415088	2.26[.03]

Table 8: Short-run estimates of energy consumption from ARDL model (China)

Dependent variable: dEGUSE

Regressors	Coefficient	T-Ratio[Prob]
dEGUSE1	.48	2.59[.016]
dUPOPNT	144920.1	2.33[.028]
dUPOPNT1	145080.8	1.44[.163]
dDCGDP	-2422.3	-2.12[.044]
dDCGDP1	2012.3	1.43[.165]
dDCGDP2	1975.7	1.42[.167]
dGDPGR	-7371.9	-2.45[.021]
dINDGDP	11919.6	1.79[.084]
dINDGDP1	7456.7	1.23[.231]
dC	480779.6	2.54[.018]
ecm(-1)	-.34	-3.46[.002]

R-Bar-Squared : .74

DW-statistic : 2.23

The short-run estimates of energy consumption from the ARDL model for China, as shown in Table 8. Dependent variable: dEGUSE The coefficient for dEGUSE1 is 0.48 with a t-ratio of 2.59 (significant at $p < 0.016$), indicating that a one-unit increase in the lagged first difference of energy consumption leads to an increase in energy consumption by approximately 0.48 units in the short run. Similarly, the coefficient for dUPOPNT is 144920.1 with a t-ratio of 2.33 (significant at $p < 0.028$), suggesting that a one-unit increase in the first difference of the proportion of urban population to total population leads to an increase in energy consumption by approximately 144920.1 units in the short run. The coefficient for dDCGDP is -2422.3 with a t-ratio of -2.12 (significant at $p < 0.044$), indicating that a one-unit increase in the first difference of the ratio of industrial output to GDP leads to a decrease in energy consumption by approximately 2422.3 units in the short run.
Similarly, the coefficient for dGDPGR is -7371.9 with a t-ratio of -2.45 (significant at $p < 0.021$), suggesting that a one-unit increase in the first difference of GDP growth rate leads to a decrease in energy consumption by approximately 7371.9 units in the short run. Finally, the coefficient for the error correction term (ecm(-1)) is -0.34 with a t-ratio of -3.46 (significant at $p < 0.002$), implying that deviations from the long-run equilibrium are corrected by approximately 0.34 units in the short run.

6. CONCLUSIONS

The study aimed to elucidate whether energy consumption is primarily driven by economic growth or influenced by factors such as urbanization and financial development. Given the challenges associated with energy production constraints and its scarcity, coupled with frequent international price spikes, understanding the intricate relationship among these variables is imperative for shaping future energy policies and fostering accelerated economic development, particularly for emerging economies. Utilizing the ARDL approach to cointegration procedure, the study reveals that similar results are observed in the long-run for both economies concerning the energy demand model. Specifically, it is found that the proportion of urban population to total population exerts a significant impact on energy consumption. Additionally, financial development, GDP growth rate, and industrial output exhibit negative influences on energy use in both economies. These findings shed light on the complex interplay between economic factors and energy consumption patterns, emphasizing the need for holistic and sustainable energy policies that take into account urbanization trends, financial development dynamics, and industrial growth trajectories. By addressing these multifaceted factors, policymakers can formulate strategies aimed at promoting efficient energy use, enhancing economic growth, and mitigating the challenges posed by energy scarcity and environmental concerns.

Upon analyzing the results of our economic growth model, our study reveals intriguing findings regarding the long-run relationships between various factors and economic growth in India and China. For India, it is observed that an increasing proportion of urban population negatively impacts economic growth in the long run. However, while energy use exhibits a positive impact on economic growth, its magnitude of influence is relatively lower. Surprisingly, the study finds that financial development and industrial output do not significantly explain economic growth in India. In contrast, the long-run estimates for China present a different picture. Here, an increasing proportion of urban population is found to have a favorable impact on economic growth. However, financial development, energy use, and industrial output in total output are all identified as factors exerting adverse impacts on the economic growth rate. This finding for China is particularly surprising, as it contradicts the prevailing notion that the country's growth is primarily driven by the performance of the manufacturing or industrial sector, which has historically contributed significantly to economic growth through exports. These unexpected results challenge the conventional wisdom surrounding the drivers of economic growth in both India and China and warrant further investigation into the underlying dynamics shaping their respective growth trajectories. Moreover, they underscore the importance of considering a diverse range of factors and contextual nuances when formulating economic policies aimed at fostering sustainable and inclusive growth in emerging economies.

These divergent findings hold significant implications for the policy frameworks of both countries. While the increasing urban population negatively affects India's economic growth, it serves as a contributor to China's economic expansion. Similarly, while energy use contributes positively to India's economic growth, the opposite holds true for China, despite its status as a more energy-intensive economy. These observations suggest that India may be leveraging energy resources more effectively, whereas China appears to be capitalizing on the efficient utilization of its workforce. This discrepancy could stem from inherent differences in the entrepreneurial spirit and industrial dynamics of the two nations. China's entrepreneurial culture and robust manufacturing sector have traditionally fueled its growth, particularly through exports. Conversely, in India, the manufacturing sector may not be making significant contributions to growth and exports, potentially indicating saturation in the growth rates of these sectors. These nuanced insights underscore the need for tailored policy interventions that account for the unique economic structures and developmental trajectories of India and China. By recognizing and addressing these disparities, policymakers can better harness the respective strengths of each economy while mitigating the challenges posed by their specific contexts. The findings underscore the importance of channeling redundant labor into more productive sectors to enhance overall economic efficiency and effectiveness. Given the significant impact of energy use on economic growth, both India and China should exercise caution in their energy utilization practices, particularly considering the adverse effect on China's growth and the modest yet favorable contribution to India's economic expansion. Notably, the study highlights that financial sector development does not lead to increased energy use; instead, it appears to deter energy consumption in both countries—a notable discovery. However, the negative correlation between industrial growth and China's economic growth rate presents a perplexing scenario that warrants further investigation. This anomaly suggests complexities within China's industrial landscape that may require deeper analysis to elucidate. Further research efforts dedicated to exploring this relationship could provide valuable insights into the dynamics of China's economic growth and industrial development, contributing to more informed policy decisions and strategic interventions.

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