The influence path and dynamic relationship between economic development, industrial structure upgrading, urbanization, urban–rural income gap, and electricity consumption in China

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Abstract
Considering China’s goal of carbon neutrality, understanding the influence path and dynamic correlation between electricity consumption and relevant factors is essential for formulating a reasonable electricity development strategy and promoting high-quality socio-economic development. Based on panel data of 30 provinces in China from 2000 to 2019, this study adopts the panel VAR model for research, with four notable findings. (1) Economic development, urbanization, and the urban–rural income gap directly affect electricity consumption. Industrial structure upgrading can affect electricity consumption through economic development and urbanization. Electricity consumption only directly affects economic development, whereas the effect on the other three variables could be transmitted through economic development. (2) Electricity consumption first inhibits and then promotes industrial structure upgrading, and it inhibits the urban–rural income gap. (3) Industrial structure upgrading first promotes and then inhibits electricity consumption. The urban–rural income gap inhibits electricity consumption. (4) Industrial structure upgrading and the widening income gap might hinder economic development through the adverse effect on electricity consumption. Based on these findings, several policy suggestions are proposed.

KEYWORDS
dynamic relationship, electricity consumption, high-quality development, influence path, urban–rural income gap

1 | INTRODUCTION
In September 2020, China proposed to achieve peak carbon dioxide emissions by 2030 and carbon neutrality by 2060. In November 2020, China asserted that it is entirely possible to reach the current level of high-income countries by the end of the 14th Five-Year Plan and double its economic aggregate by 2035. Given the limited amount of energy and increasing energy demand associated with economic development, achieving carbon
neutrality and doubling its economic aggregate are challenges as well as opportunities for China.

The essence of China’s achieving carbon neutrality and doubling its economic aggregate requires high-quality socio-economic development, achieving which means not only doubling the economy but also ensuring environmental protection, resource conservation, and advancing social equity in energy and the environment. Energy consumption is a significant material basis for realizing high-quality socio-economic development. As the major mode of energy consumption, electricity has become the main form of energy use in China’s modern economic life and correlates highly with modern socio-economic development.1,2 The link between electricity consumption and high-quality socio-economic development is roughly reflected in the four aspects of environment, resources, society, and economy. At the environmental level, because of the characteristics of resource endowment, the power generation installed in China is dominated by thermal power. From 2000 to 2019, the proportion of thermal power generation is greater than 70%; less than 30% of power generation comes from clean energy (see Figure 1). Thermal power generation has great demand for coal, which has always had the largest share of China’s primary energy consumption structure. Approximately half the coal consumption is used to generate electricity, resulting in massive carbon emissions and environmental pollution. Above 40% of the carbon emissions are from the electric power industry. Overreliance on coal for power generation is a significant source of carbon emissions in China.3 At the resource level, China’s current circumstances of fossil energy use as the main source of power generation will not fundamentally change in the short term. With the development and use of fossil energy, energy resources are growing increasingly scarce. The dependence of modern socio-economic development on electricity is the primary factor restricting energy resources.4 At the social level, as the energy of production and life, the electricity consumption also affects urban development. Promoting urbanization and narrowing the income gap are significant approaches to addressing imbalances of urban–rural development, social equity, and justice issues. The widening urban–rural income gap might lead to not only increases in electricity consumption by urban residents but also the consumption of low-quality energy by rural residents with lower income levels; thus, the income gap could potentially affect electricity consumption. At the economic level, electricity consumption is closely related to economic development5,6 and is a barometer of economic development.7 Due to the limitation of total energy and environmental resources, China must strategically develop a new high-quality economic growth model to decrease economic development’s reliance on energy consumption. China is currently realizing economic transformation through leading industrial adjustment. Therefore, this paper investigates electricity consumption, economic development, industrial structure upgrading, urbanization, and the urban–rural income gap as one interconnected system.

Figures 2 and 3 present the electricity consumption, economic development, industrial structure upgrading, urbanization, and the urban–rural income gap by province in 2000 and 2019. As can be seen from the two figures, Beijing, Liaoning, Zhejiang, Shanghai,
Fujian, and Guangdong have high levels of electricity consumption, economic development, industrial structure upgrading, and urbanization, and a narrow urban–rural income gap, whereas Henan, Anhui, Jiangxi, and Guizhou have low levels of electricity consumption, economic development, industrial structure upgrading, and urbanization and a wide urban–rural income gap. Certain similarities exist in the distribution characteristics of economic development, industrial structure upgrading, urbanization, and electricity consumption among provinces, whereas the provincial distribution characteristics of electricity consumption and the urban–rural income gap seem the opposite. Therefore, there may be a reason to expect a relationship between economic development, industrial structure, urbanization, and energy/electricity consumption recently. These studies could be roughly divided into two categories. One category is the research regarding the link between energy/electricity consumption and one of the other three indicators. Most scholars investigated the causality between economic development and energy/electricity consumption, and the results are frequently inconsistent for countries at different stages of industrialization and urbanization. Some evidence has supported a Granger causal relationship between economic development and energy/electricity consumption in Angola, the United Arab Emirates, China, and multiple European countries. Some studies have indicated a unidirectional causality from energy consumption to economic development in the United States and new emerging-market countries. Gregori and Tiwari revealed a one-way causality from electricity to the economy in the short-run and a long-term bidirectional causality from electricity to
economy in China. Additionally, the relationship between urbanization and energy/electricity consumption presents complex characteristics across countries. Some studies asserted a positive relationship between the two indicators in some developed countries in Europe. Karanfil and Li indicated that higher electricity consumption induces urbanization in Sub-Saharan Africa, while the causal relationship runs reverse in other developing countries. Similarly, the study results regarding the link between industrial structure upgrading and energy/electricity consumption also vary. Vaqar and Muhammad concluded that industrial structure upgrading is negatively correlated with energy consumption. Narayanan and Sahu asserted that industrial structure upgrading could increase India’s energy consumption. Li and Yuan found a positive relationship between industrial growth and electricity consumption using a quantile-on-quantile approach in China. Zhang et al. and An et al. contended that industrial structure optimization is practical for reducing electricity consumption. The other category is research regarding the link between energy/electricity consumption and two of the other three variables. For example, Zhao and Zhu studied the link between industrial restructuring, energy consumption, and economic development and found a bidirectional causality between industrial structure upgrading and the economic development of China. Yu et al. confirmed that electricity in the BRICS countries is positively associated with industrial and economic development, using Vector Auto Regression. Wang et al. showed a bidirectional causal relationship between economic development, urbanization and electricity consumption overall. Lin and Zhu found urbanization and the proportion of secondary industry to have an important influence on electricity consumption. The link between economic development, industrial structure upgrading, urbanization, and energy/electricity consumption appears inconsistent across countries.

FIGURE 3 Electricity consumption, economic development, industrial structure upgrading, urbanization, and urban–rural income gap by province in 2019. (A) Electricity consumption per capita (kWh), (B) real per capita gross regional product (yuan), (C) regional industrial structure hierarchical coefficient, (D) urbanization, (E) ratio of urban residents’ disposable income to rural residents’ disposable income.
including China. It is necessary to further examine the correlations between economic development, industrial structure upgrading, urbanization, and electricity consumption. Few scholars have brought economic development, industrial structure, urbanization, and electricity consumption into the same framework towards investigating the influence path or bidirectional dynamic relationships.

Substantial existing research regarding the influence of income inequality on the environment concludes that inequality is closely related to pollution emissions. Energy/electricity consumption is a key factor of environmental pollution; however, the question of whether energy/electricity consumption affects income inequality remains unanswered. At present, the research work closest to this issue examines the influence of renewable energy on income inequality in developed countries. In addition, some studies have demonstrated that income inequality has an impact on economic development and some have shown that energy/electricity consumption is closely related to economic development. Based on this, the impact of income inequality on renewable energy consumption has attracted the attention of some scholars recently. However, research regarding whether income inequality affects electricity consumption is rare. No research has explored the two-way interaction between electricity consumption and the urban–rural income gap.

The possible innovations of the study are threefold. (1) Income inequality is related to economic development, and electricity consumption is related to economic development. Meanwhile, income inequality has an influence on the environment, whereof energy consumption is a key contributor. These assertions have been demonstrated in empirical studies; however, studies regarding correlations between income inequality and electricity consumption are largely overlooked. This study introduces the urban–rural income gap variable to examine the bidirectional interaction between electricity consumption and income inequality. (2) Based on the close link between electricity consumption and high-quality socio-economic development, this study is the first to examine economic growth, industrial structure, urbanization, the urban–rural income gap, and electricity consumption in the same framework. (3) Previous studies on electricity consumption and its related factors largely focus on the causal or interaction relationship between variables. Studies on the influence path between variables are rare. This study uses the panel vector autoregression (panel VAR) model to explore the influence path and bidirectional dynamic relationship between economic growth, industrial structure, urbanization, the urban–rural income gap, and electricity consumption. This study could help fill the identified research gap. In practice, the study is not only conducive to the rational planning of electric power industry development and the formulation of a rational and effective power development strategy but also holds the promise of promoting economic development while addressing the challenges of environmental pollution, urban and rural development imbalances, social inequity and injustice and unreasonable industrial structure.

The remainder of the study is organized into four sections. Section 2 introduces variable descriptions and model specifications. Section 3 details the measurement and results analysis. Section 4 provides the discussion, and Section 5 offers conclusions and policy implications.

2 VARIABLE DESCRIPTIONS AND MODEL SPECIFICATION

2.1 Variable descriptions

This paper uses annual data of China’s 30 provinces (except Tibet Autonomous Region, Hong Kong, Macao, and Taiwan) pertaining to the 2000–2019 period for analyses, integrating electricity consumption, economic development, industrial structure upgrading, urbanization, and the urban–rural income gap into the same model. The selected variables are described below.

Electricity consumption. This variable is expressed as per capita electricity consumption, measured by dividing regional electricity consumption by the number of year-end resident populations.

Economic development. This variable is expressed as real per capita gross regional product, which is normalized at 1999 constant prices.

Industrial structure upgrading. The general rules of industrial structure development are as follows. (1) The proportion of primary industry declines, while the proportion of secondary and tertiary industries rises. (2) The proportion of primary and secondary industries declines, but the proportion of tertiary industries continues to rise. Therefore, selecting the industrial structure hierarchical coefficient, including the three industrial structures as the proxy index of industrial structure upgrading, can fully reflect industrial structure upgrading and evolution. The definition formula is as follows:

\[ w = \sum_{i=1}^{3} ts_i \times i = ts_1 + 2ts_2 + 3ts_3, \]

where \( ts_1, ts_2, \) and \( ts_3 \) represent the proportion of primary, secondary, and tertiary industries in the regional economy, respectively. A high \( w \) value indicates
a high industrial structure hierarchical coefficient and a high level of industrial structure upgrading.

Urbanization. This variable is calculated by dividing the population of permanent urban residents by the general population.\textsuperscript{46,47}

Urban-rural income gap. This variable is commonly estimated using the Gini index or the urban–rural disposable income ratio (the specific value of urban residents’ per capita disposable income to that of rural residents).\textsuperscript{46} Which among the various methods of calculating the Gini index is more authoritative is an open question in academic circles. The urban–rural disposable income ratio is the income that residents can actually spend, thus better reflecting the actual income levels of urban and rural residents. This study adopts the second method to calculate the urban–rural income gap.

\section*{2.2 Data sources}

For empirical analysis, this paper uses annual data from 2000 to 2019. One reason is that the data in these years are relatively complete, whereas earlier years have some missing values. Another reason is that China’s economy has experienced a new surge since the turn of the 21st century. Electricity consumption has been increasing. The process of urbanization and industrialization has also accelerated. Therefore, the selection of panel data from 2000 to 2019 has significant research implications. The basic data of this study are gathered from the China Statistical Yearbook (2001–2020) and the China Energy Statistical Yearbook (2001–2020). To maintain data consistency, the electricity consumption and economic development variables of this paper are processed with logarithms, and industrial structure upgrading, urbanization, and the urban–rural income gap as endogenous variables, integrating them into one framework for research. The panel VAR model is written as

\[ Y_{i,t} = \alpha_0 + \sum_{j=1}^{p} \beta_j Y_{i,t-j} + \gamma_i + \eta_i + \mu_{i,t}. \]

\[ Y_{i,t}, Y_{i,t-j} \text{ and } \beta_j \text{ can be extended as} \]

\[ Y_{i,t} = \begin{bmatrix} \ln reelec_{i,t} \\ \ln rgd_{i,t} \\ ts_{i,t} \\ u\eta_i \\ gap_{i,t} \end{bmatrix}, \]

\[ Y_{i,t-j} = \begin{bmatrix} \ln reelec_{i,t-j} \\ \ln rgd_{i,t-j} \\ ts_{i,t-j} \\ u\eta_{i-j} \\ gap_{i,t-j} \end{bmatrix}, \]

\[ \beta_j = \begin{bmatrix} \beta_{11}^{(j)} & \beta_{12}^{(j)} & \beta_{13}^{(j)} & \beta_{14}^{(j)} & \beta_{15}^{(j)} \\ \beta_{21}^{(j)} & \beta_{22}^{(j)} & \beta_{23}^{(j)} & \beta_{24}^{(j)} & \beta_{25}^{(j)} \\ \beta_{31}^{(j)} & \beta_{32}^{(j)} & \beta_{33}^{(j)} & \beta_{34}^{(j)} & \beta_{35}^{(j)} \\ \beta_{41}^{(j)} & \beta_{42}^{(j)} & \beta_{43}^{(j)} & \beta_{44}^{(j)} & \beta_{45}^{(j)} \\ \beta_{51}^{(j)} & \beta_{52}^{(j)} & \beta_{53}^{(j)} & \beta_{54}^{(j)} & \beta_{55}^{(j)} \end{bmatrix}, \]

where \( Y_{i,t} \) is a vector of 5 \times 1; \( i \) represents the different individuals, \( i = 1, 2, ..., 30; \) \( t \) refers to the different points over time, \( t = 2000, 2001, ..., 2019; \) \( Y_{i,t-j} \) indicates all the endogenous variables with a lag term of order \( j; \) \( \beta_j \) is the lag effect matrix to be evaluated; \( p \) is the order of hysteresis; \( \gamma_i \) represents the time effect, indicating the influence of factors that change over time, such as national policies; \( \eta_i \) represents the individual effect, which reflects interprovincial heterogeneity, such as

\begin{table} [h!]
\centering
\caption{Descriptive statistics of all variables}
\label{tab:1}
\begin{tabular}{|l|l|c|c|c|c|c|}
\hline
Variable & Abbreviation & Mean & Median & Maximum & Minimum & Std. dev. \\
\hline
Electricity consumption & lnrelec & 7.871 & 7.910 & 9.647 & 6.187 & 0.684 \\
Economic development & lnrngdp & 9.809 & 9.845 & 11.687 & 7.890 & 0.750 \\
Industrial structure upgrading & ts & 2.296 & 2.270 & 2.810 & 2.030 & 0.133 \\
Urbanization & ur & 0.500 & 0.484 & 0.896 & 0.204 & 0.151 \\
Urban–rural income Gap & gap & 2.867 & 2.755 & 4.759 & 1.845 & 0.567 \\
\hline
\end{tabular}
\end{table}
resource endowment, climate, and other relevant considerations; $\mu_{it}$ is the random error term and $\alpha_0$ represents the constant term.

The panel VAR model equations are as follows:

$$\ln\text{reelec}_{i,t} = \alpha_{01} + \sum_{j=1}^{p} (\beta_{11}^{(j)} \ln\text{reelec}_{i,t-j})$$

$$+ \beta_{12}^{(j)} \ln\text{rgdp}_{i,t-j} + \beta_{13}^{(j)} \text{ts}_{i,t-j}$$

$$+ \beta_{14}^{(j)} \text{ur}_{i,t-j} + \beta_{15}^{(j)} \text{gap}_{i,t-j}) + \gamma_{i1} + \eta_{i1}$$

$$+ \mu_{it},$$

$$\ln\text{rgdp}_{i,t} = \alpha_{02} + \sum_{j=1}^{p} (\beta_{21}^{(j)} \ln\text{reelec}_{i,t-j})$$

$$+ \beta_{22}^{(j)} \ln\text{rgdp}_{i,t-j} + \beta_{23}^{(j)} \text{ts}_{i,t-j}$$

$$+ \beta_{24}^{(j)} \text{ur}_{i,t-j} + \beta_{25}^{(j)} \text{gap}_{i,t-j}) + \gamma_{i2} + \eta_{i2}$$

$$+ \mu_{2it},$$

$$\text{ts}_{i,t} = \alpha_{03} + \sum_{j=1}^{p} (\beta_{31}^{(j)} \ln\text{reelec}_{i,t-j} + \beta_{32}^{(j)} \ln\text{rgdp}_{i,t-j})$$

$$+ \beta_{33}^{(j)} \text{ts}_{i,t-j} + \beta_{34}^{(j)} \text{ur}_{i,t-j} + \beta_{35}^{(j)} \text{gap}_{i,t-j}) + \gamma_{i3}$$

$$+ \eta_{i3} + \mu_{3it},$$

$$\text{ur}_{i,t} = \alpha_{04} + \sum_{j=1}^{p} (\beta_{41}^{(j)} \ln\text{reelec}_{i,t-j} + \beta_{42}^{(j)} \ln\text{rgdp}_{i,t-j})$$

$$+ \beta_{43}^{(j)} \text{ts}_{i,t-j} + \beta_{44}^{(j)} \text{ur}_{i,t-j} + \beta_{45}^{(j)} \text{gap}_{i,t-j}) + \gamma_{i4}$$

$$+ \eta_{i4} + \mu_{4it},$$

$$\text{gap}_{i,t} = \alpha_{05} + \sum_{j=1}^{p} (\beta_{51}^{(j)} \ln\text{reelec}_{i,t-j} + \beta_{52}^{(j)} \ln\text{rgdp}_{i,t-j})$$

$$+ \beta_{53}^{(j)} \text{ts}_{i,t-j} + \beta_{54}^{(j)} \text{ur}_{i,t-j} + \beta_{55}^{(j)} \text{gap}_{i,t-j})$$

$$+ \gamma_{i5} + \eta_{i5} + \mu_{5it}.$$

The GMM estimation of the model

3.1 Unit root test

This study uses the LLC, IPS, and Fisher ADF methods to perform the panel unit root test for all variables. The test results all reject the hypothesis of “existence of unit root” (see Table 2), indicating that the original sequences of lnreelec, lnrgdp, ts, ur, and gap are stationary. Additionally, the panel VAR model can be constructed.

3.2 Hysteresis order selection

This study selects three lag periods to determine the best lag length on the basis of the Akaike information criterion (AIC), Bayesian information criterion (BIC), and Hannan-Quinn information criterion (HQIC). On the grounds of the minimum information criterion, the best lag length is determined to be 2 (see Table 3).

3.3 GMM estimation of the model

This study uses the Stata15.1 software package to estimate the system GMM of the panel VAR model. The GMM estimation coefficient of the model is obtained cross-sectional and forward mean difference methods to eliminate time and individual effects before the panel VAR model is used for system-generalized moment estimation. Using the impulse response function, the paper examines the influence of the disturbance term on each variable. Finally, the study analyses the contribution of disturbance terms to every variable, using variance decomposition.

### Table 2: Panel unit root test results

| Variable  | LLC t-Statistic | p-Value | IPS t-Statistic | p-Value | ADF t-Statistic | p-Value |
|-----------|-----------------|---------|-----------------|---------|----------------|---------|
| lnreelec  | -4.733***       | 0.006   | -1.342*         | 0.089   | 9.139***       | 0.000   |
| lnrgdp    | -5.528***       | 0.000   | -3.299***       | 0.000   | 7.536***       | 0.000   |
| ts        | -2.844***       | 0.002   | -1.900**        | 0.029   | 11.339***      | 0.000   |
| ur        | -4.961***       | 0.000   | -2.051**        | 0.020   | 10.694***      | 0.000   |
| gap       | -4.859***       | 0.000   | -1.896**        | 0.029   | 9.009***       | 0.000   |

***, ** and * denote $p < 1\%$, $p < 5\%$, and $p < 10\%$, respectively.
through 500 Monte-Carlo simulations, as presented in Table 4.

Table 4 reveals a significant dynamic relationship between economic development, industrial structure upgrading, urbanization, the urban–rural income gap, and electricity consumption.

The electricity consumption variable significantly affects the economic development variable but has no significant influence on the other variables. The economic development variable affects industrial structure upgrading and the urban–rural income gap significantly. Industrial structure upgrading and the urban–rural income gap have a significant influence on urbanization. Electricity consumption only appears to have a direct influence on economic development; however, its impacts on the other variables can be transmitted through economic development. The impact of the economic development, urbanization, and urban–rural income gap variables on electricity consumption are significant. Industrial structure upgrading has no significant influence on electricity consumption but significantly influences economic development and urbanization. Economic development, urbanization, and the urban–rural income gap appear to have a direct influence on electricity consumption. Similarly, industrial structure upgrading can influence electricity consumption through economic development and urbanization. The influence path of the other four variables and the electricity consumption variable is presented in Figure 4.

Figure 4 indicates that electricity consumption is most closely related to the economic development variable. Additionally, because the estimated coefficient of the panel VAR model only reflects part of the relationship between variables, it is difficult to explain the economic significance of parameter estimation and the influence of its changes on other variables. The interaction between variables cannot be completely reflected. Therefore, the paper further analyses the dynamic correlation between variables and the influence degree.

| Lag order | AIC       | BIC       | HQIC      |
|-----------|-----------|-----------|-----------|
| 1         | −20.6362  | −19.1146  | −20.0381  |
| 2         | −21.6075  | −19.7812ab| −20.8877a |
| 3         | −21.6290a | −19.4645  | −20.7735  |

Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion; HQIC, Hannan-Quinn information criterion.

*aThe best lag order.

**TABLE 3** Results of hysteresis order test

**TABLE 4** Panel VAR model regression results

**FIGURE 4** Influence path of the variables

***, ** and * denote p < 1%, p < 5%, and p < 10%, respectively.
3.4 | Impulse response function

The orthogonal impulse response is extremely sensitive to variable order. The Granger causality test is used in the study to determine the order of variables. The results show that the causal relationship between variables is consistent with that which is depicted in Figure 4. That is to say, \( ts \), \( gap \), \( ur \), and \( \ln \, \text{reelec} \) are all Granger causes of \( \ln \, \text{rgdp} \). Meanwhile, \( \ln \, \text{rgdp} \), \( ur \) and \( gap \) are all Granger causes of \( \ln \, \text{reelec} \); \( ur \), \( gap \) and \( \ln \, \text{rgdp} \) are all Granger causes of \( ts \); \( ts \) and \( gap \) are Granger causes of \( ur \); and \( \ln \, \text{rgdp} \) is the Granger cause of \( gap \). Thus, \( gap \) is regarded as the “most exogenous,” followed by \( ur \). The “most endogenous” is thought to be \( \ln \, \text{rgdp} \). As \( \ln \, \text{reelec} \) and \( ts \) both have three Granger causes, the possible order of variables is either \( gap \), \( ur \), \( \ln \, \text{reelec} \), \( ts \) and \( \ln \, \text{rgdp} \) or \( gap \), \( ur \), \( ts \), \( \ln \, \text{reelec} \) and \( \ln \, \text{rgdp} \). The orthogonal impulse responses of the two orders are calculated in this paper. Through comparison, the main conclusions are essentially the same. Figure 5 shows the impulse response diagram with the variables \( gap \), \( ur \), \( ts \), \( \ln \, \text{reelec} \) and \( \ln \, \text{rgdp} \) in that order.

3.4.1 | Impact of the electricity consumption variable on the other variables

The fourth column of Figure 5 presents the dynamic response diagram of variables affected by the electricity consumption variable.

(1) The fifth row of the fourth column in Figure 5 demonstrates that economic development quickly receives a positive response under the impact of the electricity consumption variable and that the positive response peaks in the eighth period and then levels off. The growth of electricity consumption can attract investment in power infrastructure and drive the
development of related industries, thereby promoting economic growth.

(2) Industrial structure upgrading is negatively affected in the first five periods; then, it becomes positive and gradually stabilizes under the impact of the electricity consumption variable, as is shown in the third row of the fourth column in Figure 5. This indicates that electricity consumption first inhibits and then promotes industrial structure upgrading. The effect of electricity consumption on industrial structure upgrading can be transmitted through the economic development variable. Economic development guides the upgrading of industrial structures. China is still in an unfinished stage of industrialization, and the industrialization development is not yet mature. Effective upgrading of the industrial structure should be coordinated with the level of economic development and must be established on the basis of mature industrialization. At present, China’s industrial structure remains somewhat unreasonable, and the connection between industrial structure upgrading and economic development is not yet fully coordinated. When the industrial structure upgrading process becomes coordinated with the economic development process, electricity consumption could promote industrial structure upgrading through economic development.

(3) Under the impact of the electricity consumption variable, urbanization development is positively affected (See the second row of the fourth column in Figure 5.), and the urban–rural income gap is negatively affected (See the first row and the fourth column in Figure 5.). As electricity consumption promotes economic development, economic development improves urban infrastructure and the supporting service system, promotes the flow of factors, improves labor capital level, and attracts cheap rural labor to cities and towns. Thus, it improves social labor productivity, overcomes disparities in urban and rural income levels, and promotes urbanization.

3.4.2 | Impact of the other four variables on the electricity consumption variable

The fourth row of Figure 5 is the impulse response diagram of the electricity consumption variable, which is affected by all four of the other variables.

(1) Under the impact of the economic development variable (See the fifth column of the fourth row in Figure 5.), electricity consumption is positively affected, reaching a peak in the seventh period and then stabilizing, which indicates that economic growth could result in increased electricity consumption. Reliance on coal for China’s power generation will not change fundamentally in the short term. Electricity consumption growth might put pressure on the environment and affect the achievement of energy-saving and emission reduction targets. It is an exceedingly challenging task for China to simultaneously realize economic growth and green development under the power production pattern dominated by coal-based power generation.

(2) The third column of the fourth row in Figure 5 reveals the influence of industrial structure upgrading on electricity consumption. Electricity consumption is positively affected, reaching its peak in the first period under the impact of industrial structure upgrading. The influence then becomes negative after the callback of 0 in the sixth period. Industrial structure upgrading indicates technological progress, the formation of high-tech industries, and the transformation and upgrading of traditional industries. China is still in the stage of industrialization. Secondary industry is the main driving force of economic development. The scale expansion of secondary industry and the continuous refinement of the industrial division requires more electricity, whereas many small- and medium-sized enterprises in the industrial sectors predominantly use backward technology. Subsequently, the reduction in electricity consumption brought about by technological advances might not offset the increase in electricity demand in the short term; however, with the passage of time and energy-intensive industries’ successful transformation, capital/technology-intensive industries become the leading industries, and the proportion of tertiary industry keeps rising. The energy-saving effect of industrial structure upgrading will become increasingly prominent.

(3) The second column of the fourth row of Figure 5 reveals that electricity consumption is positively affected by the impact of urbanization. Rapid urbanization development leads to the concentration of productive activities and the flow of people from the countryside into cities in addition to the concentration of energy consumption for production and living in cities. It also promotes continuous improvement of urban infrastructure and supporting service systems, driving a significant increase in electricity demand.

(4) Electricity consumption is negatively affected under the influence of the urban–rural income gap variable (See the first column of the fourth row in Figure 5.). Disparities in urban and rural income levels might lead to the electricity consumption fault between urban and rural. On the one hand, because of the relatively backward infrastructure construction and lower-income level, the overall electricity consumption level in rural areas is relatively low. On the other hand, when urban electricity consumption is high enough, the
driving effect of urban areas on electricity consumption is limited as the marginal utility of urban residents to electricity consumption decreases. This might lead to the urban–rural income gap affecting electricity consumption in the whole economy.

In addition, as China's economic development depends on energy consumption, electricity consumption promotes economic growth. This implies that industrial structure upgrading and the urban–rural income gap might hinder economic growth through the adverse impact on electricity consumption (See the first and third columns of the fifth row in Figure 5.). Industry is the key foundation for industrial structure upgrading. The core of industrial structure upgrading is innovation and industrial development transformation, referring to improvements in efficiency and energy consumption reduction. Nevertheless, China remains at a development stage of industrialization. The nation's economic growth still depends on energy consumption, and the connection between industrial structure upgrading and economic development is not yet fully coordinated. Industrial structure upgrading has a certain inhibitory influence on economic development. China should endeavor to upgrade its industrial structure, ensuring that the road to industrialization is truly complete and substantial. It is essential to avert the country's low-end manufacturing transformation from failing, the development of high-end manufacturing from becoming unsatisfactory, high-level production factors from failing to agglomerate in industrial sectors where primary innovation is most needed, and the economy from entering the “middle-income trap.” The disparities in urban and rural income levels could lead to the fault of social consumption demand, low-income human capital investment restrictions, and social instability, affecting electricity demand and economic growth. China's power production pattern is dominated by thermal power generation, and higher income inequality indicates lower environmental pressure. However, the urban–rural income gap does not benefit the sustainable economic development of China. Therefore, the government should strengthen policy support to overcome disparities in urban–rural income levels.

### 3.4.3 | Impact of the economic development variable on the other variables

The fifth column of Figure 5 shows the impulse response diagram of industrial structure upgrading, urbanization development, and urban–rural income gap affected by the economic development variable. The results indicate that the influence trends of the electricity consumption and economic development variables on the other variables are basically the same. It also confirms the close link between economic development and electricity consumption in China. The urban–rural income gap variable responds rapidly and negatively, and the effect begins to stabilize in the seventh period under the impact of the economic development variable (See the first row of the fifth column in Figure 5.). This verifies the effectiveness of China's long-term policy in closing the income gap.

### 3.5 | Variance decomposition

Table 5 presents the variance decomposition values of each variable in the 10th, 20th and 30th prediction periods. The contribution value of each variable in the 20th and 30th prediction periods presents a slight difference, indicating that the system is stable after 20 prediction periods.

According to the results of the 30th forecast period, the contribution of electricity consumption, economic development, industrial structure upgrading, urbanization, and the urban–rural income gap to electricity consumption is 60.27%, 24.38%, 1.18%, 7.49%, and 6.68%, respectively. This demonstrates that the variance contribution value of electricity consumption is primarily influenced by itself, followed by the economic development and urbanization variables. In addition, the
variance contribution values of the electricity consumption variable to economic development, industrial structure upgrading, urbanization, and the urban–rural income gap are 16.92%, 1.74%, 2.24%, and 1.01%, respectively, indicating that the electricity consumption variable has the largest contribution to the variance of the economic development variable, followed by the urbanization variable. When combined with GMM estimation results and impulse response results, the variable most closely related to electricity consumption appears to be economic development, followed by the urbanization and urban–rural income gap variables. The connection between industrial structure upgrading and electricity consumption is the weakest.

In addition, the urban–rural income gap is significantly influenced by its fluctuation in the 10th period, reaching 65.47%. Over time, this influence decreases but remains at 48.26% in the 30th phase. It could be concluded that the urban–rural income gap has strong path dependence, confirming the challenge of closing the income gap in China.

3.6 | Robustness test

The aforementioned results are tested by changing the variable order and selecting a subsample to avoid bias. After the Monte-Carlo simulation of impulse response and variance decomposition, the primary results of the two methods remain consistent with the results, confirming the robustness of the model. Because of the length constraints, robustness test results are not listed in this study but are available upon request.

4 | DISCUSSION

Based on the empirical results of our panel VAR model, several primary conclusions could be discussed further.

First, the results indicate that electricity consumption and economic development can directly influence one another. Urbanization and the urban–rural income gap have a direct influence on electricity consumption. Additionally, there is no direct connection between electricity consumption and industrial structure upgrading in China, consistent with the findings of existing studies. The results reveal that the influence of electricity consumption on urbanization and the urban–rural income gap can be transmitted through economic development, not proposed previously by scholars. Ghosh and Kanjila found a one-way causal relationship from energy consumption to economic activity and from economic activity to urbanization, similar to the result. This paper also contends that industrial structure upgrading impacts electricity consumption through economic development. Industrial structure upgrading indicates the level of optimization of industrial structure and the stage of economic development. The influence of industrial structure upgrading on energy consumption is related to the stage of economic development. Therefore, industrial structure upgrading might have a more direct relationship with economic development than that which electricity consumption might have. Furthermore, scholars have not studied the two-way interaction between electricity consumption and the urban–rural income gap. This study fills the research gap and might have policy implications.

Second, industrial structure upgrading first promotes and then inhibits electricity consumption, and the urban–rural income gap inhibits electricity consumption. Vaqar and Muhammad indicated that industrial structure upgrading is negatively related to energy consumption. Dong and Hao found that income inequality impacts electricity consumption increasingly negatively. These findings are in line with the conclusions of this paper; however, most studies have ignored electricity consumption's temporary positive response to industrial structure upgrading. The upgrading of industrial structure implies industry replacement and energy efficiency improvement. The influence of industrial structure upgrading on electricity consumption is related to the economic development stage. China is still in an unfinished stage of rapid industrialization, and the scale of China's secondary industry continues to expand. Many small- and medium-sized enterprises in the secondary industry are technologically backward. When the reduction in electricity consumption brought about by technological effects is not sufficient to offset the increase in electricity consumption brought about by scale expansion in the short term, industrial structure upgrading might increase electricity consumption. Additionally, higher-income inequality inhibits electricity consumption and does not benefit the sustainable economic development of China. Therefore, the government should strengthen policy support to overcome disparities in urban–rural income levels.

Third, industrial structure upgrading and growing income inequality might hinder economic development through a negative influence on electricity consumption. Although emphasizing industrial structure upgrading, a more reliable industrial policy is to prioritize industrial structure rationalization to realize sustainable growth of the Chinese economy. Rodrik asserted that premature deindustrialization and enhancement of the proportion of the service industry weakens sustainable economic
development in underdeveloped countries. As China's development has entered a new normal stage, the industrial structure has been constantly upgraded, but economic growth has slowed down. Accordingly, blindly emphasizing industrial structure upgrading cannot bring long-term economic development. In contrast, Wan et al. verified that the link between inequality and growth is negative. Lee and Son indicated that the adverse effect of the income gap on economic development is much more obvious in less developed countries. Dong and Hao found the urban–rural income gap capable of hindering economic growth through a negative impact on electricity consumption. The findings of the above studies are consistent with the results of this paper.

Three limitations of the paper should be noted. (1) Industrial structure upgrading can influence electricity consumption through economic development and urbanization. The influence of electricity consumption on industrial structure upgrading, urbanization, and the urban–rural income gap can be transmitted through economic development. This paper only presents the influence path, without further analyzing the influence mechanism, using the model. (2) Future studies could consider the different regions of China to examine regional differences in the relationship between variables. (3) Industrial structure includes the two dimensions of industrial structure rationalization and industrial structure upgrading. This study only explores the interactive link between industrial structure upgrading and electricity consumption. Further studies could examine the connection between industrial structure rationalization and electricity consumption.

5 CONCLUSIONS AND POLICY IMPLICATIONS

5.1 Conclusions

Based on the panel data of 30 provinces in China from 2000 to 2019 and using a panel VAR model, this paper investigates the influence path and bidirectional dynamic correlation between economic development, industrial structure upgrading, urbanization, the urban–rural income gap, and electricity consumption, quantitatively measuring each variable's degree of dynamic influence. This study is conducive not only to the rational planning of electric power industry development and the formulation of an effective power development strategy but also to promote economic development while helping address environmental pollution, urban–rural development imbalances, social inequity, injustice, and unreasonable industrial structure challenges. The primary empirical results are as follows.

First, economic development, urbanization, and the urban–rural income gap directly affect electricity consumption. Industrial structure upgrading could affect electricity consumption through economic development and urbanization. Electricity consumption only has a direct influence on economic development. The influence on industrial structure upgrading, urbanization, and the urban–rural income gap variables can be transmitted through economic development. The variable most closely related to electricity consumption is economic development, followed by the urbanization and urban–rural income gap variables. Coming in last is the industrial structure upgrading variable.

Second, economic development and urbanization increase electricity consumption. Electricity consumption boosts economic development and urbanization. As coal has always had the largest share of China's primary energy consumption structure, overreliance on coal for power generation is a significant source of carbon emissions in China. Therefore, it is an exceedingly challenging task for China to simultaneously realize economic growth, urbanization development, and low-carbon development under the power production pattern dominated by coal-based power generation.

Third, electricity consumption first restrains and then promotes industrial structure upgrading, and it restrainsthe urban–rural income gap. Industrial structure upgrading first promotes and then inhibits electricity consumption. The urban–rural income gap inhibits electricity consumption. As China's economic development depends on energy consumption, electricity consumption directly affects economic development. In the long run, industrial structure upgrading and growing income inequality might hinder economic development through their negative influence on electricity consumption.

5.2 Policy implications

On the basis of the above conclusions, we propose four policy implications.

(1) Electricity consumption promotes economic development, and economic development inevitably increases electricity consumption. China's current circumstances of reliance on coal as the main source of power generation will not change fundamentally in the short term. Under the condition that environmental pollution is temporarily unavoidable, the government should optimize resource allocation, address the imbalance of urban–rural development and promote social equity and justice through rational distribution of electricity.

(2) The government should focus on transforming and upgrading the electric power industry. In the short
term, priority should be given to the development of clean coal and clean and efficient coal-based power generation technologies to reduce coal consumption as much as possible. In the long term, electricity generation must be converted to renewable energy to relieve pressure on the environment and resource limitations.

(3) The government should avoid over-emphasizing the upgrading of industrial structure, which should be based on complete industrialization and be implemented in coordination with economic development. Focusing on the coordination of output and factor structures promotes industrial structure rationalization and consolidates the long-term mechanism of economic growth. This way, rational adjustment of the industrial structure can inject new impetus into the economy, minimize the inhibition effect on economic growth brought about by industrial structure upgrading and avoid the inhibition effect of electricity consumption on industrial structure upgrading caused by uncoordinated economic and industrial structure development.

(4) The government must endeavor to raise rural incomes and implement measures to overcome urban-rural income inequality. It should be fair and just in distribution, take proper care of rural areas, give rural areas added preferential treatment, remove barriers to the mobility factors of urban and rural areas and promote the equality of development opportunities and conditions between rural and urban industries. The government should increase input to rural production factors, close the gap between urban and rural production factors, and strive to realize coordinated urbanization and urban and rural development.

AUTHOR CONTRIBUTIONS
Mei Song: conceptualization, writing-review & editing, supervision, project administration. Liyan Zhang: methodology, writing-original draft, software, visualization. Mengxue Li: visualization, formal analysis.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

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