Analysis of the Factors Influencing Electricity Prices From an Industry Chain Perspective

Longyu Wang[1a], Zheng Cao[1b*], Caiyue Yang[1c*], Xinyi Hou[1d], Ying Zhang[1e], Xuan wang[2f]

[a]wlysjtu@163.com, [b*]gellever@126.com, [c*]1757499693@qq.com, [d]584109679@qq.com, [e]jessiein@163.com, [f]646193808@qq.com

[1]State Grid Jibei Electric Power Co., Ltd. Marketing Service Center, No. 87, Nanbinhe Road, Xicheng District, Beijing, China
[2]State Grid Qinhuangdao Power Supply Co., Ltd.No. 50, Haiyang Road, Haigang District, Qinhuangdao, Hebei

Abstract—Under the background of the continuous promotion of electricity market reform and the gradually active trading markets such as carbon emission rights and green certificates, the relationship between electricity prices and various market prices is gradually close. Therefore, based on the perspective of the power industry chain, on the basis of analyzing the cost and income composition of the upstream and downstream power enterprises, combined with other electricity related markets, this paper analyzes the influencing factors of the electricity price under the market-oriented transaction, and makes an empirical analysis of the influencing factors of the analyzed electricity price based on the Kendall synergy coefficient, which provides a reference for the market entities to predict the risk in advance.

Keywords-component; Electricity market; Cost benefit analysis; Electricity price; Analysis of influencing factors

1 Introduction

The stability of electricity prices is one of the most important conditions for the normal functioning of society, so the hedging of the risk of abnormal fluctuations in electricity prices is of vital importance to participants in the electricity market. As the construction of the electricity market progresses, the relationship between electricity prices and the prices and supply of upstream primary energy as well as downstream products of important enterprises is gradually tightening. In addition, with the improvement and development of the carbon market, green certificate market and other related markets, the impact of carbon emissions trading prices as well as green certificate prices on electricity prices will also gradually. In short, with the gradual reform of the electricity market, the prices of products related to the electricity industry will influence the behaviour of the participants in the electricity market, thus transferring the price fluctuations of products related to the electricity industry to the electricity price. To this end, it is important to understand the factors influencing electricity prices and the extent to which each factor affects electricity prices in order for electricity market players to take risk prevention measures in advance. Based on the perspective of the electricity industry chain, this paper analyses the impact factors of electricity prices under market-based trading based on the analysis of the cost and revenue components of upstream and downstream enterprises of electricity, in

conjunction with other electricity-related markets, to provide reference for market players to make risk predictions in advance.

2 Current status of research on factors influencing electricity prices

Most of the current research on the factors influencing electricity prices has focused on the study of the impact on a particular electricity price. The literature [1] analyses the factors influencing the marginal electricity price at the nodes of the electricity spot market from three perspectives: the power side, the grid side and the load side. Literature [2] similarly analysed the factors influencing nodal electricity prices from four perspectives: system load, incoming water, unit offer and line transmission. However, all authors in this category ignore the impact of price fluctuations in other markets on electricity prices. Literature [3] analysed the factors influencing the spot price of electricity, taking into account the situation of the main body types on the generation side, the laying of domestic power lines and the electricity auxiliary service market. However, under the double carbon target, the construction of new power systems in China's electricity is steadily advancing, the installed capacity of renewable energy is steadily rising, and the impact of fluctuations in the supply of renewable energy on electricity prices cannot be ignored. Literature [4] analysed the impact of coal prices, central bank loan interest rates, transmission and distribution prices in Hebei Province, photovoltaic feed-in tariffs in Hebei Province, coal prices, transmission and distribution prices, and average feed-in tariffs on average residential consumption electricity prices in Hebei Province, and found that coal prices and transmission and distribution prices are important influencing factors on electricity prices. However, as the construction of the electricity market advances, the customer side will no longer be the recipient of the price, so its impact on electricity prices cannot be ignored.

In addition, some other scholars have analysed the factors influencing electricity prices for single-side subjects, such as literature [5] and literature [6], but under market-based trading, the prices traded by various types of market players affect each other, and analysis targeting only one type of market player will no longer be applicable.

3 Analysis of the cost-benefit composition of upstream and downstream market players in the power industry chain

3.1 Analysis of the cost-benefit components of coal power companies

For coal power companies, the largest proportion of their costs is the cost of coal. According to the research, most of the units of the standard coal consumption between 300 grams to 400 grams, the recent price of 5500 kcal power coal in Qinhuangdao fluctuates between 600 yuan / ton, the calorific value of standard coal is 7000 kcal, if the recent coal-fired units of the standard coal consumption of electricity to 350 grams, electricity feed-in tariff to 0.5 yuan, then the enterprise degree of electricity coal cost is about 0.27 yuan, degree of coal cost This represents over 50% of the revenue per kWh. In addition to coal costs, coal-fired power companies have daily operating and fixed costs, as well as the cost of purchasing carbon credits when their carbon emissions exceed their allowances. Coal-fired companies derive their revenues from three main sources: firstly, from the sale of electricity generated; secondly, from the regulation

of the electricity system, including ancillary services and capacity compensation; and thirdly, from additional revenues, such as heating revenues. In summary, the components of the costs and revenues of a coal power company are shown below.

$$C_{thermal} = C_{coal} + C_{operating} + C_{depreciation} + C_{carbon}$$
(1)

$$R_{thermal} = R_{power} + R_{regulatory} + R_{premium}$$
(2)

$$C_{coal} = K * Q_{generation} * P_{coal} * CV$$
(3)

$C_{thermal}$, C_{coal}, $C_{operating}$, $C_{depreciation}$ and C_{carbon} are the cost of coal combustion, operating costs, depreciation and carbon trading costs of coal-fired power companies respectively; $R_{thermal}$, R_{coal}, $R_{operating}$, $R_{depreciation}$ and R_{carbon} are the revenue from electricity, ancillary services and additional revenue of coal-fired power companies respectively; K is the standard coal consumption per unit of electricity of coal-fired units; $Q_{generation}$ is the total amount of electricity generated by coal-fired companies; P_{coal} is the price of coal; CV is the conversion coefficient between the calorific value of coal purchased by the enterprise and the calorific value of standard coal.

3.2 Analysis of the cost-benefit components of renewable energy generators

For renewable energy generators, whose primary energy sources are natural resources such as wind and light, there is no economic cost; their largest costs are the fixed costs required for their construction, including the cost of components and installation costs. In addition, because renewable energy generation is highly volatile and stochastic, renewable energy generators are required to pay regulation costs in addition to their day-to-day operating costs. Renewable energy generators have a revenue from the sale of green certificates in addition to the revenue from electricity energy. In summary, the components of the costs and revenues of a renewable energy generator are shown below.

$$C_{renewable} = C_{greendepreciation} + C_{greenoperating} + C_{regulatory}$$
(4)

$$R_{renewable} = R_{greenpower} + R_{certificate}$$
(5)

$C_{renewable}$, $C_{greendepreciation}$, $C_{greenoperating}$ and $C_{regulatory}$ are the depreciation, operating costs and ancillary service costs of renewable energy enterprises respectively; $R_{renewable}$, $R_{greenpower}$ and $C_{certificate}$ are the energy revenues of renewable energy enterprises respectively.

3.3 Analysis of the cost-benefit components of electricity consumers

For electricity users, electricity is an important source of energy to maintain their normal production and operation, and some of them also involve processes such as electrolysis or electroplating in their production process, so electricity costs are a relatively large part of the

costs for this category of electricity users. In addition, there are raw material costs, operating costs, fixed costs and some additional costs for this category. The revenues of large industrial customers are mainly derived from the sales of their products or services, in addition to some additional revenues. In summary, the cost components of large industrial users are shown below.

$$C_{users} = C_{power} + C_{materail} + C_{usersoperating} + C_{usersdepreciation}$$

(6)

$$R_{users} = R_{producte} + R_{userspremium}$$

(7)

C_{users} and R_{users} is the total cost and total revenue of the electricity consumers; where C_{power}, $C_{materail}$, $C_{useroperating}$ and $C_{usersdepreciation}$ are the electricity consumers' cost of electricity, raw material cost, operating cost and depreciation respectively; $R_{producte}$ and $R_{uerspremium}$ are the electricity consumers' product revenue and additional revenue respectively.

4 Analysis of the factors influencing electricity prices based on electricity-related markets

4.1 Analysis of relevant influencing factors on the power generation side

From the above analysis, it can be found that coal price has a greater impact on the cost of power generation of coal power enterprises, and coal power is still the main force to ensure the supply of electricity in China, so coal price is one of the important influencing factors of electricity price. In addition, practice has proven that large fluctuations in coal prices will seriously affect the normal operation of coal power companies. CEC released the "2021-2022 national electricity supply and demand situation analysis and forecast report" shows that 2021 because of the rising price of coal led to the national coal power enterprises coal procurement cost additional 600 billion yuan or so, since August large power generation group coal power plate overall loss, August-November part of the group's coal power plate loss reached 100%, the annual cumulative loss reached 80% The cumulative loss for the year reached 80%.

In the case of renewable energy, the main factors affecting its electricity supply are changes in natural conditions. From the perspective of a hydroelectric power producer, the main influencing factors on its electricity production are wind energy density and wind speed; for a photovoltaic power producer, the main influencing factors on its electricity production are light intensity and light duration; for a hydroelectric power producer, the main influencing factors on its electricity production are average reservoir water level.

4.2 Analysis of relevant influencing factors on the electricity consumption side

For the electricity side, electricity is closely related to its production activities and the way it affects the price of electricity is mainly by influencing the demand for electricity. When the economic situation is favourable or when the cost of raw materials falls, production will increase and so will the demand for electricity, and when the supply of electricity remains unchanged, the price of electricity will rise. The factors that affect the price of electricity on the electricity

side include product sales, product prices, raw material costs and the elasticity of demand for electricity, all of which affect the price of electricity by affecting the amount of electricity consumed by consumers. In addition, factors affecting electricity consumption on the electricity side include unexpected events such as the New Crown epidemic. 2021 has seen the sporadic emergence of epidemics across China so far, and the volatility of electricity consumption by electricity users has increased significantly, which is also reflected in the volatility of electricity prices in the context of a well-developed electricity market system.

4.3 Analysis of other relevant market influencing factors

China's carbon emissions trading market has been officially launched on July 16, 2021. According to the data released by the National Energy Administration, a total of 2,162 key emission units in the power generation industry have been included, covering approximately 4.5 billion tonnes of carbon dioxide emissions. the cumulative number of enterprises participating in trading in 2021 exceeds half of the total number of key emission units, and the compliance rate of market allowances reaches over 99.5%. In addition, on 7 September 2021, the national green power trading pilot was officially launched, and China has now promoted the establishment of a set of standardised and effective green certificates issuance and trading system, with 5,690 subscribers and 4,526,503 green certificates subscribed by 31 October 2022. With the gradual activation of carbon emissions trading and green certificate trading, the price of green certificates and the price of carbon emissions will also affect electricity prices by influencing the trading behaviour of power market players such as coal power companies, renewable energy companies and large industrial users.

Table 1 Summary of Factors Affecting Electricity Price

Pathways of Influence	Name of influencing factor	Pathways of Influence	Name of influencing factor	Pathways of Influence	Name of influencing factor
Generation side	Coal prices	Electricity side	Prices of major raw materials	Other routes	Price of carbon credits
	Wind energy density		Product sales revenue		Green Card Prices
	Wind strength		Sudden events		Gross National Product
	Duration of light		Elasticity of demand for electricity		Interest rates
	Light intensity				Stock Price
	Average reservoir level				

In addition, from a social development perspective, changes in the economic situation may also have an impact on electricity prices. Thus, economic indicators such as interest rates, stock prices and GDP may also be a factor in the impact of electricity prices.

From the above analysis, it can be seen that there are three main pathways that can have an impact on electricity prices: firstly, through the generation side; secondly, the customer side; and thirdly, the market associated with the electricity market, as summarised in the table below.

5 Empirical Analysis of Factors Affecting Electricity Price Based on Kendall Synergy Coefficient

Kendall W coefficient, also known as Kendall synergetic coefficient, is a method to express the correlation degree of multi column rank variables. There are two main calculation methods, one for the evaluation does not have the same grade, and the other for the evaluation has the same grade.It is generally believed that Kendall's coefficient of synergy is less than 0.2, indicating poor consistency; The consistency between 0.2 and 0.4 is general; 0.4 to 0.6 indicates medium consistency; 0.6 to 0.8 indicates a strong degree of consistency; 0.8 to 1.0 indicates a strong degree of consistency.

The W calculation formula for non existence of the same evaluation grade is as follows:

$$W = \frac{12\sum R_i^2}{K^2 N(N^2 - 1)} - \frac{3(N+1)}{N-1}$$

(8)

In the formula, R_i represents the sum of K grades obtained by the evaluation object; N represents the number of objects to be graded; K represents the number of raters.

The W calculation formula for non existence of the same evaluation grade is as follows

$$W = \frac{\sum R_i^2 - \frac{\left(\sum R_i\right)^2}{N}}{\frac{1}{12}K^2(N^3 - N) - K\sum \frac{n^3 - n}{12}}$$

(9)

Where n is the number of the same grade.

In order to verify the credibility of the above electricity price influencing factors, the author investigated the views of researchers in several electricity related fields on the above electricity price influencing factors, and asked them to rank the above electricity price influencing factors according to their own relevant cognition and research. The higher the influence of electricity price, the higher the ranking. Subsequently, 8 persons were randomly selected from all the results for analysis, and their Kendall W coefficients were calculated by SPSS software. The analysis results are shown in Table 2 and Table 3.

Table 2 Rank average of influencing factors

Name of influencing factors	Rank average	Ranking
Coal price	1.13	1
Wind energy density	4.94	3
Wind intensity	4.63	2
Light duration	5.25	5
Light intensity	6.50	6
Average water level of reservoir	4.94	3
Price of main raw materials	6.56	7
Product sales revenue	9.00	10

Sudden events	12.00	13
Elasticity of electricity demand	8.50	8
Carbon emission right price	8.81	9
Green certificate price	9.81	11
Gross National Product	11.13	12
interest rate	12.69	14
price of stock	14.13	15

It can be seen from the above statistical results that most evaluators believe that coal price is the most important influencing factor of electricity price, followed by wind power intensity. This is because coal power is still the main power supply in China, and compared with other renewable energy power generation, wind power utilization hours are higher. In addition, it can also be found from the above data that most evaluators believe that the factors that affect the electricity side behavior are not as important as those that affect the electricity generation side behavior, which indirectly reflects the strong market power of the electricity generation side in China's electricity market.

Table 3 Statistical Test Results

Entry Name	Number
entry name	8
Kendall W coefficient	0.645
Chi square	72.219
Degrees of freedom	14
Degrees of freedom	0.000

It can be seen from the above results that the significant P value is 0.000, greater than 0.05, and the original hypothesis is not tenable, indicating that the consistency is statistically significant. In addition, the Kendall W coefficient is 0.645, which is between 0.6 and 0.8, indicating that the evaluators have a strong degree of consistency and credibility in their evaluation of the above electricity price influencing factors.

6 Conclusion

Under the background of the continuous promotion of electricity market reform and the gradually active trading markets such as carbon emission rights and green certificates, the relationship between electricity prices and various market prices is gradually close. Based on the perspective of industrial chain, this paper analyzes the factors that may affect the price of electricity on the basis of building the cost benefit model of the main players in the electricity market, and makes an empirical analysis of the factors that affect the price of electricity based on Kendall's synergy coefficient, providing reference for the market players to conduct risk management.

Acknowledgments

of the project team for their help. The learning materials you provided are the key to writing this paper. Thank you again!

References

[1]Zhao Shuai, Wang Sen, Yang Xiaojing, Zhou Liansheng. Study on the impact of "source-grid-load" factors on marginal tariffs at power spot market nodes[J]. Price Theory and Practice, 2021(02):83-86+139.

[2] Li Zehong, Zeng Yangchao, Zhou Changyou, Vinegar Yuanke, Xiao Peng. Analysis of nodal electricity price influence factors based on electricity spot market clearing simulation[J]. Electrical Technology,2020,21(05):41-47.

[3] Li Xiaojun, He Chengming, Liu Shaoyun, Cao Ruilin, Zhang Jun. Research on the key influencing factors of electricity price at the node of power spot market[J]. Power Equipment Management,2021(09):173-175.

[4] Niu Ziyao, Nie Chunyang, Tian Zhongjing. Exploring the factors influencing the sales tariff and policy effects in Hebei Province[J]. Industrial Innovation Research,2022(11):57-59.

[5] Gao Hong, Dang Zhiqin, Jia Huihui, Zhang Guoxing. Research on factors affecting grid price of wind power projects based on network level analysis [J]. Journal of Hebei Institute of Architecture and Engineering, 2017,35 (03): 70-73

[6] Sun Bingxiang, Ruan Haijun, Xu Wenzhong, Jiang Jiuchun, Gong Minming. Quantitative analysis of influencing factors of electric vehicle charging price based on static non cooperative game [J]. Journal of Electrotechnics, 2016, 31 (21): 75-85