Multi-dimensional Evaluation and Analysis of Wind Power Investment Development Format under Supply Side Reform

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Abstract. Through reviewing relevant literatures, this paper summarizes and analyzes the existing research results of wind power development level, and constructs a reasonable, scientific and comprehensive comprehensive evaluation index system for wind power development level, and compares the development level of wind power in recent years. In this paper, the research environment of supply-side reform is aimed at the development status and influence mechanism of wind power industry. Based on the logistic model and learning curve analysis of wind power industry development, this paper studies the evolution of wind power industry and the evaluation system of wind power investment development in China under the supply-side reform background. Empirical analysis, calculate and characterize various indicators of wind power industry from multiple angles, and improve the comprehensive evaluation and analysis of wind power investment development forms. The full text shows that wind energy is a renewable, non-polluting, low-energy, and promising energy source. It is a strategic choice for countries around the world to vigorously develop clean energy such as wind energy.

1. Introduction

Based on the analysis of China's wind power development status, as of now, the development of China's wind power industry is still in a weak stage of high cost and low price. However, from another perspective, the current competitive disadvantage does not fully explain the lack of industrial development potential[1]. For emerging technologies, the relatively high cost and relatively weak competitiveness experienced in the initial stage is the only way for industrial development[2]. Whether the industry can finally flourish depends on whether the industry and new technologies have strong vitality and broad market development space[3]. In the long run, whether it is the technical feasibility of replacing traditional electricity with wind power or the value of wind power to the social environment, it can reflect the great potential of the development of wind power industry[4].

This paper uses the industrial evolution theory: Logistic model, learning curve and other methods to construct a model for the development and evolution of wind power industry, and simulates and analyzes the important indicators involved in the wind power industry chain. The word industry can be understood as the “state of development of the industry”. Through the research and study of the wind power industry chain, the indicators of business analysis are understood, and the indicators that affect the state of the industry are: market, subject, efficiency, efficiency, Maturity level, competitiveness analysis, etc. This chapter performs some characterization and calculations on these indicators to analyze their impact on wind power industry.

The dimensions are classified as shown in the following table:
2. Dimensional Evaluation and Analysis of Wind Power Investment Scale Based on Logistic Model and Learning Curve

2.1. Construction of Logistic Model
Experience has shown that the development and commercialization of any emerging technology generally goes through several stages: research and development, technical demonstrations and commercial demonstrations, large-scale cost reduction and large-scale promotion. At these stages, the spread of new technologies can have a significant "learning" effect. In the early stage of the development of new technologies, products lacked market competitiveness, and the popularity and promotion volume grew slowly. However, with the passage of time, the continuous self-improvement of product technology and the continuous accumulation of production, the cost has shown a downward trend. At the same time, the output growth rate began to accelerate until it reached its peak. Then, the growth rate began to slow down and decline until the new technology penetration reached saturation.

According to the growth and development rules of the new technology industry, this process will inevitably undergo various stages of large-scale promotion and final cost reduction. Therefore, it can be found that these stages are in good agreement with the development of Logistic growth curves and learning curves. Therefore, the Logistic model and the learning curve are used as the basis for constructing the wind power industry evolution analysis model, which is in good agreement with the characteristics of the wind power industry development law. This topic has strong analytical research and practical application value.

As a typical model for describing technological innovation, the growth curve conforms to the evolution process of the industrial chain and is a process of knowledge innovation, diffusion, deepening and division of labor. The results show that in the long process of technological innovation, product performance based on one type of technology will approach the limit N of technical performance along the S-shaped curve, and the inflection point generated in this method is usually half of the limit.
When the cumulative output at time $t$ is $X_t$, the law of $X_t$ changing with time can be expressed as a differential equation:

$$\frac{dX_t}{dt} = \alpha X_t \left(1 - \frac{X_t}{N}\right)$$

(1)

In the formula, $X_t = X_0; i = 0, 1, ..., n$ is the state variable describing the evolution process, $\alpha$ is the velocity coefficient of the system evolution, $N$ is the peak of the technical performance limit, and $1 - X_t/N$ is the remaining growth rate of the system. As time goes by, it gradually decreases to approach 0, which is called the deceleration factor.

Assumed that at the beginning of the evolution, the state variable is known, denoted as $X_0$, first transform the logistic model formula, which is recorded as:

$$\int_{X_0}^{X_t} \frac{dX_t}{X_t \left(1 - \frac{X_t}{N}\right)} = \int_0^{t} \alpha dt$$

(2)

Then perform the integration and the result is:

$$\int_{X_0}^{X_t} \frac{N}{X_t \left(1 - \frac{X_t}{N}\right)} = \int_0^{t} \alpha dt$$

(3)

Easy to solve:

$$X_t = \frac{N}{1 + \frac{N - X_0}{X_0} e^{-\alpha t}}$$

(4)

Make:

$$\frac{N - X_0}{X_0} = A$$

(5)

Solutions have to:

$$X_t = \frac{N}{1 + Ae^{-\alpha t}}$$

(6)

In the formula, $\alpha$ is the growth rate coefficient, $A$ is determined by the initial condition, and $N$ is the technical performance limit peak.

The Logistic model can describe the model of the process of s-type growth of the system. It is widely used in many fields such as biology, pathology, socioeconomics, management, etc. It can also be applied to the analysis of industrial evolution process.

The industrial system is formed by many companies with certain similar characteristics, and its development is constrained by its own growth ability, resources and environment. The development of industrial systems often goes through processes such as pregnancy, growth, maturity and decline. It follows a pattern: in the early stages of its development, scale growth is getting faster and faster, and at some point, growth rates are maximized. Then it gradually slows down until the number reaches the growth limit and the overall evolution of the S shape.

If the logic model is applied to the evolution analysis of an industrial system, $X_t$ represents the cumulative output of the entire industry at time $t$. Is the growth rate of the industry; $A$ is a constant, determined by the initial conditions of the industrial system, including the input structure of the factor,
productivity, relative profitability of the investment, and other factors. N represents the limit of output
growth during industrial development, or the maximum value of market demand. If the research question
is of practical significance, the parameter range should satisfy $> 0$, $N >> 0$.

Let the accumulated installed capacity in the $t$-th period be $X_t$, $N_t$ is the maximum economic
development amount of the $t$-th wind power, $\alpha$ is the growth rate of the industry, and $A$ is a constant,
which is determined by the initial conditions of the industrial system. The redefined logistic equation is:

$$X_t = \frac{N}{1 + Ae^{-\alpha t}}$$  \hspace{1cm} (7)

At the same time, China's wind power equipment manufacturing industry can also be seen as a diffusion
process of new technologies. Its development was developed on the basis of the introduction and
absorption of foreign technology. It is in line with the development of the logistics growth curve.
Therefore, the development mode of installed capacity of wind power equipment in China is as follows:

$$G_t = \frac{X_t}{N}$$  \hspace{1cm} (8)

$T$ indicates the time required for the development amount to reach half of the maximum economic
developable amount. The characteristic parameter $T$ and the initial wind energy resource development
rate $R_0$ are two parameter data simultaneous equations, namely:

$$T = \frac{\ln A}{\beta}, \hspace{1cm} R_0 = \frac{1}{1 + A}$$  \hspace{1cm} (9)

Solutions have to $A = \frac{1 - R_0}{R_0}$, $\alpha = \frac{\ln (1 - R_0) - \ln R_0}{T}$.

One of the key issues in applying the logistic model to the study of wind power industry evolution
is to find that the wind power industry development amount reaches the maximum economic
developable amount $N_t$. Wind power generation is a way of generating electricity by using wind energy
resources under natural conditions. The level of development is closely related to the total amount of
wind energy and the distribution of wind energy. For the use of natural resources, its level is constrained
by two important indicators:
First of all, the exploitable amount of wind power resources under natural conditions is closely related
to the current natural conditions and the level of development and utilization of natural resources.
Second, the amount of economically exploitable resources at this stage is closely related
to the current natural conditions and the level of development and utilization of natural resources.

As a new energy technology, the initial promotion and application of wind power will be constrained
by factors such as development and utilization costs, resource prices, and economic development levels.

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As a new energy technology, the initial promotion and application of wind power will be constrained
by factors such as economy, policy, system, cost, competitive price, and maximum technological
developability. Therefore, the maximum economic developability ($N_t$) of the wind power industry is
different at different times. Without the constraints of capital, policy, and competitive prices, the value
of $N_t$ is only related to competitive products. It is considered as the cost ratio $k_t$ for wind power and
competitive products, which is a function of $N_{max}$. When the cost of wind power is more than 6 times
the cost of competitive products, $k_t > 6$. At this time, the new energy of wind power is at a market
disadvantage and does not have the ability to compete with competitive products. The development
speed is extremely slow and the growth rate is 0, $N_t = N_{t-1}$. When the cost of wind power is more than
20% within 6 times of the cost of competitive products, the development of wind power products begins
to enter the commercial development period. Although the market competitiveness at this time is not
strong enough, there is great potential. There are corresponding policies to encourage and not affected
by the financial constraints, the industry can attract strategic investors to enter. At this time, the $N_t$ of
the industry is greatly affected by the cost factor, and the corresponding formula is:

$$N_t = (k_t) \cdot N_{max}$$  \hspace{1cm} (10)

$\gamma$ is a parameter that indicates the extent to which the gap between wind power costs and competitive
products affects the maximum economic development of wind power.

When the ratio of the cost of wind power products to the cost of competitive industries is less than
20%, that is, when $k_t \leqslant 1.2$, the market competitiveness of the wind power industry is significantly
improved, and the price is less affected, namely:
Logistic models can now be used to quantitatively describe the evolution of wind power industry development $X_t$ in different periods.

2.2. Application of learning curve

Establish a learning curve structure model:

$$ L = A N^{-\lambda} $$

$L$ represents the average cost, and $N$ represents the cumulative output, at which time $A > 0$. When $\lambda = 0$, $L = A$, $N$ does not have any effect on $L$. At this time, there is no learning effect; when $\lambda = 1, L = A/N$, the learning effect is sufficient. In general, the larger the $\lambda$, the more obvious the learning effect.

In the logistic model, the learning curve needs to be transformed into

$$ C_t = C_0 \left( \frac{X_t}{X_0} \right)^{-\lambda} $$

$C_t$ is the cost of the $t$-th wind power industry, $C_0$ is the initial cost, $X_t$ is the $t$-stage development quantity, $X_0$ is the initial development quantity, and $\lambda$ is the learning index, reflecting the impact of the development speed of the wind power industry on the installed cost.

2.3. Model parameter determination and calculation process

The logistic model was analyzed at a certain base period. According to the statistical data and actual development of China's wind power industry, combined with the requirements of China's wind power industry development plan, 48 years from 2002 to 2050 were selected for analysis.

(1) Empirical parameter $\gamma$

The empirical parameter $\gamma$ indicates the extent to which the gap between wind power costs and competitive products affects the maximum economic development of wind power. The empirical value $\gamma = 2.5$ is generally obtained by consulting the data.

(2) Maximum technical exploitability $N_{\text{max}}$

$N_{\text{max}}$ depends on the state of natural wind energy resources. According to the relevant data, the total land area of China's wind power with an average density of 150W/m$^2$ and above is about 200,000km$^2$. According to the minimum 3MW/km$^2$ and the maximum limit of 5MW/km$^2$, the wind power on the land can always be calculated. The development volume is about 600 million to 1 billion kilowatts. Relevant data show that the sea area of the shallow sea along the coastline of China is about 157,000 square kilometers. If 10% to 20% of the sea surface can be used by the wind power industry, the wind turbine can calculate the total amount of offshore wind power according to the calculation of 5MW per square kilometer. About 100 million to 200 million kilowatts. According to relevant data, it is possible to take $N_{\text{max}} = 800$ million kW.

On the basis of the logistic model, for the sake of simplicity, the time required to achieve half of the maximum economic development amount of wind power development is regarded as a fixed parameter. By analyzing the natural resource status of wind power at home and abroad and the development status of wind power equipment, it is desirable. $T$ is 30 years.

(3) Other parameters

The initial industrial development volume $X_0$ was determined by the installed capacity of China's cumulative installed wind power in 2002, namely:

$$ X_0 = 46.842 \text{ (10,000 kW)} $$

The rated power $G_0$ of the domestically produced wind turbines was determined by the accumulated domestic wind power installed capacity in 2002:

$$ G_0 = 5.415 \text{ (10,000 kW)} $$

$C_0 = 0.65$ (yuan/kWh)

The competitive industry cost is set at 0.36 yuan per kWh.

At this point, the equation parameters $A$, $\beta$, etc. can be calculated from known values:

$$ N_0 = (k_0 - \gamma N_{\text{max}} = (0.65/0.36) - 2.5 \times 80000 \approx 160 \text{ kW}$$
The same method can determine the parameters B, \( \beta \), namely:

\[
B = 7.65 \\
\beta = 0.34
\]

Through the conclusion of relevant similar industry evolution analysis, the final learning rate index is \( \lambda = 0.12 \).

Based on the above-mentioned logistic model process, the computerized programming of China's wind power equipment installed capacity, the market share of domestic wind power equipment and the evolution of wind power costs were simulated by computer programming from 2002 to 2050.

| years | Installed capacity | Wind power cost | Domestic wind power equipment production |
|-------|--------------------|-----------------|------------------------------------------|
|       | Cumulative total: X | growth rate | Wind power cost: C | growth rate | Cumulative output: G | growth rate | market share: M |
| 2011  | 597.81  | 31.4 | 0.48 | -3.23 | 439.99 | 45.5 | 0.74 |
| 2012  | 785.02  | 31.3 | 0.46 | -3.22 | 625.36 | 42.1 | 0.80 |
| 2013  | 1029.85 | 31.2 | 0.45 | -3.2 | 871.48 | 39.4 | 0.85 |
| 2014  | 1349.42 | 31.0 | 0.43 | -3.19 | 1194.88 | 37.1 | 0.89 |
| 2015  | 1765.65 | 30.8 | 0.42 | -3.17 | 1616.8 | 35.3 | 0.92 |
| 2016  | 2258.21 | 27.9 | 0.41 | -2.91 | 2119.34 | 31.1 | 0.94 |
| 2017  | 2790.23 | 23.6 | 0.4 | -2.51 | 2665.89 | 25.8 | 0.96 |
| 2018  | 3422.25 | 22.7 | 0.39 | -2.42 | 3312.29 | 24.2 | 0.97 |
| 2019  | 4179.3  | 22.1 | 0.38 | -2.37 | 4082.83 | 23.3 | 0.98 |
| 2020  | 5082.45 | 21.6 | 0.37 | -2.32 | 4998.38 | 22.4 | 0.98 |
| 2021  | 6153.27 | 21.1 | 0.36 | -2.27 | 6080.48 | 21.6 | 0.99 |
| 2022  | 7413.78 | 20.5 | 0.35 | -2.21 | 7351.15 | 20.9 | 0.99 |
| 2023  | 8885.37 | 19.8 | 0.35 | -2.15 | 8831.81 | 20.1 | 0.99 |
| 2024  | 10587.23 | 19.2 | 0.34 | -2.08 | 10541.73 | 19.4 | 1.00 |
| 2025  | 12534.46 | 18.4 | 0.33 | -2.01 | 12496.07 | 18.5 | 1.00 |
| 2026  | 14735.78 | 17.6 | 0.33 | -1.92 | 14703.62 | 17.7 | 1.00 |
| 2027  | 17191.2 | 16.7 | 0.32 | -1.83 | 17164.48 | 16.7 | 1.00 |
| 2028  | 19889.93 | 15.7 | 0.31 | -1.73 | 19867.91 | 15.8 | 1.00 |
| 2029  | 22808.84 | 14.7 | 0.31 | -1.63 | 22790.87 | 14.7 | 1.00 |
| 2030  | 25912.09 | 13.6 | 0.31 | -1.52 | 25897.56 | 13.6 | 1.00 |
| 2031  | 29152.07 | 12.5 | 0.3 | -1.4 | 29140.43 | 12.5 | 1.00 |
| 2032  | 32471.84 | 11.4 | 0.3 | -1.29 | 32462.61 | 11.4 | 1.00 |
| 2033  | 35808.88 | 10.3 | 0.29 | -1.17 | 35801.63 | 10.3 | 1.00 |
| 2034  | 39099.72 | 9.2 | 0.29 | -1.05 | 39094.09 | 9.2 | 1.00 |
| 2035  | 42284.59 | 8.1 | 0.29 | -0.94 | 42280.25 | 8.1 | 1.00 |
| 2036  | 45311.54 | 7.2 | 0.28 | -0.83 | 45308.24 | 7.2 | 1.00 |
| 2037  | 48139.43 | 6.2 | 0.28 | -0.72 | 48136.93 | 6.2 | 1.00 |
| 2038  | 50739.38 | 5.4 | 0.28 | -0.63 | 50737.5 | 5.4 | 1.00 |
| 2039  | 53094.9 | 4.6 | 0.28 | -0.54 | 53093.5 | 4.6 | 1.00 |
| 2040  | 55200.78 | 4.0 | 0.28 | -0.47 | 55199.75 | 4.0 | 1.00 |
(1) Simulation analysis of logistic evolution model of wind power installed capacity

| Year | Installed Capacity | Growth Rate | Capacity Difference | Year | Installed Capacity | Growth Rate | Capacity Difference |
|------|--------------------|-------------|---------------------|------|--------------------|-------------|---------------------|
| 2041 | 57061.26           | 3.4         | 0.28                | 2042 | 58687.8           | 2.9         | 0.28                |
| 2043 | 60096.84           | 2.4         | 0.28                | 2044 | 61307.83          | 2.0         | 0.28                |
| 2045 | 62341.54           | 1.7         | 0.27                | 2046 | 63218.8           | 1.4         | 0.27                |
| 2047 | 63959.62           | 1.2         | 0.27                | 2048 | 64582.62          | 1.0         | 0.27                |
| 2049 | 65104.71           | 0.8         | 0.27                | 2050 | 65540.95          | 0.7         | 0.27                |

Figure 2 Evolution curve of installed capacity of domestic wind power equipment

(2) Simulation analysis of logistic evolution model of domestic wind power equipment manufacturing industry

Figure 3 Domestic wind power equipment market share evolution chart

(3) Simulation analysis of wind power cost logistic evolution model
2.4. Analysis of simulation results of logistic equation model

According to the above simulation results of wind power industry evolution based on logistic model, it can be found that the installed capacity growth rate of wind power industry is still at a low level, far lower than the actual development level and the development level of competitive industries. Therefore, the rapid growth of the wind power industry needs to adapt to the growth rate of installed capacity.

Therefore, the installed capacity of China's wind power industry has great room for development and growth. Under the current growth environment, it is conservatively estimated that China's wind power industry will enter a period of rapid growth before 2016, and the annual growth rate of wind power installed capacity will exceed 30%. From 2016 to 2020, China's installed wind power installed capacity has basically maintained an annual growth rate of more than 20%. After 2020, the indicator will decline and the growth rate will remain within 20 years, lasting about 15 years. After 2040, wind power growth has declined.

China's wind power equipment manufacturing industry will continue to accelerate the pace of localization. According to the simulation results of the non-incentive policy analysis, by 2020, the domestic wind power equipment market share can reach 98%, the domestic wind power equipment installation market has been fully developed, and the wind power equipment manufacturing industry must develop a broader international market and seek new ones. The development of space also means more intense competition with internationally renowned wind power equipment manufacturers.

The growth rate of wind power installed capacity lags far behind the actual development level. This shows that while China's wind power industry chain is growing rapidly, there is a certain degree of blindness and investment impulse.

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