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Research on Forecasting Electricity Demand of the 13th Five-year in Hebei Province

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Abstract

With the emergence of a "new economic norm" and "industrial restructuring", the electricity demand situation in Hebei province will undergo significant changes in the future. Therefore, it is essential to predict electricity demand in the 13th Five-year for power planning and construction. Considering the factors and mechanisms determining electricity demand of various sectors are different, the total electricity consumption in this paper is divided into five parts: the first industry, industry, construction, the tertiary industry and resident sectors. The electricity demand equations of different sectors are established to make predictions, respectively. The results show that the total electricity consumption will grow at an annual rate of 3.46%-3.87% during 13th Five-Year-Plan period, which would be more than 0.4234×1012 kWh in 2020. The electricity consumption growth of tertiary industry and resident sectors would raise fast, which will grow at an annual rate of 8.72%-9.15% and 6.24%-6.72% during 13th Five-Year-Plan period. Moreover, comparing with the demand structure in 13th Five-Year-Plan period, the proportion for industrial electricity demand will decline by 5%, the proportions for tertiary industry and resident sector will increase by 3% and 2%. The electricity consumption structure in Hebei province would change in the future.

Keywords*: Electricity demand, forecasting, subsectors, co-integration theory*

1. Introduction

As the foundation of the national economy, electricity production and supply provides an indispensable condition for economic development, social progress and the improvement of living standard. The incompatibility between electric industry and economic development would pose enormous impact on the national economy and people's life [1-3]. Therefore, the balance of electricity demand and supply has been one of the core problems in related researches on electricity market. With the emergence of a "new economic norm" and "industrial restructuring", the electricity demand situation in Hebei province will undergo significant changes in the future [4-5]. In order to ensure the harmonious development between electricity industry and economy development, it is essential to forecast the electricity demand in Hebei province during the 13th Five-Year-Plan period, combing the economic development planning and the goal of economic structure adjustment.

To the best of our knowledge, there are mainly two methods on the prediction of electricity demand: Elastic Coefficient Method and Demand function method [6]. Since the electrical elasticity coefficient is determined by many complex factors, it has been controversial to reflect the relationship between electricity and economy based on

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electrical elasticity coefficient. Therefore, the forecasting result of electricity demand based on elastic coefficient method exist lots of risk. Fully considering the influencing factors and mechanism, the demand function method establishes the equation between electricity demand and influencing factors based on the econometric theory. And then, according to the development situation of influencing factors, the electricity demand can be forecasted based on the demand function [7-9].

The whole society electricity demand in this paper is divided into five parts: the first industry, industry, construction, the tertiary industry and resident sectors. After the electricity demand of five sectors being forecasted, the whole society electricity demand equates to the sum of the demand of five sectors. There are three reasons we use the above forecasting framework to forecast the whole society electricity demand. First of all, the influencing factors of electricity demand in different sectors are variable. For example, factors influencing residents demand and industry demand have significant difference. The residents demand is affected by living standard and price [10]. Accordingly, the industry demand has close relevancy with GDP and energy efficiency. Secondly, the change of economic structure can be taken into consideration using the subsector forecasting method [11]. At last, since the characters of electricity demand in different sectors are different, the forecasting model should be various. Therefore, the whole society electricity demand based on subsectors can fully consider the influencing factors in different sector respectively, which can better control the prediction error and make the prediction more accurate. Meanwhile, the forecasting framework in this paper can analyze the consumption structure in the future.

2. The Basic Theory of Co-integration Theory

Regression model based on multiple linear regression model may be spurious regression when the time series are not smooth. Co-integration was firstly put forward by Granger in 1981. Engle and Granger proposed the theorem and its concrete operational framework [12]. In this theory, if the linear combination of non-stationary time series is stable, there must exist a co-integration relationship between these variables, namely the long-term equilibrium relationship. Since the time series of economic indicators are always not smooth, the co-integration theory is applied to analyze the relationship between electricity demand and economic development in Hebei province. On the one hand, a long-term equilibrium model is established based on Stationarity test and Johansen test. The specific steps are shown as follows:

(1) Stationarity test[13]

The ADF unit root test is a common method used to test the stability of a time series. The time series variable model is established as follows:

$$\Delta X_t = \alpha + \beta t + \delta X_{t-1} + \sum_{i=1}^{p} \theta_i \Delta X_{t-i} + \varepsilon_t \quad (1)$$

Where, α is constant, t is trend term, p is the optimal lag order number, ε_t is random error term. For a given significance level, when the ADF test value is less than the critical value, the time series is stable.

(2) Co-integration test[14]

Co-integration can be expressed as follows: if yt~I(d), namely yt becomes stationary after d times differencing, there must exist $\alpha = [\alpha_1, \alpha_2, ..., \alpha_k]$ makes $Z_t = \alpha X_t' \sim I(d-b)$ ($b > 0$). On this basis, $X_{1t}, X_{2t}, ..., X_{kt}$ is co-integration of (d, b) order, namely $X_t \sim C_I(d, b)$, and α co-integrated vector.

The JJ (Johansen and Juselius) co-integration test is always used to test the co-integration for multiple variables. There are two ways to test the co-integration: TRACE and MAX are commonly two output results in this test.

3. Forecasting Model of Electricity Demand in Each Sector

(1) The forecasting model of the first industrial electricity demand

The value-added of first industry ($GDP1$), electricity consumption intensity ($E1$), agricultural irrigation and drainage motor power (PG) are the key factors affecting the electricity demand of the first industrial electricity demand ($Q1$). Therefore, based on the unit root test and co-integration test of these four factors, the forecasting model is established as follows:

$$\ln Q1 = -3.8244 + 0.9286 \ln GDP1 + 0.0997 \ln PG + 13.5642 E1 \quad (2)$$

Since the coefficients of above forecasting model has been through the inspection, there is a long-term equilibrium correlation among $lnQ1$, $lnGDP1$, $E1$ and PG. From the perspective of long-term equilibrium, when the added-value of first industry increases 1%, the electricity demand increases 0.928%; when agricultural irrigation and drainage motor power increases 1%, the electricity demand increases 0.0997%; when electricity consumption intensity increases 1%, the electricity demand increases 13.56%.

(2) The forecasting model of the industry electricity demand

Considering the characters of the industry production, the value-added of industry (*GDPg*), industrial proportion of heavy industry (Mz), electricity consumption intensity of the industry (Eg) are the key factors affecting the electricity demand of the industry electricity demand (Qg) [15-16]. Therefore, based on the unit root test and co-integration test of these four factors, the forecasting model is established as follows:

$$\ln Qg = -2.2911 + 0.9985 \ln GDPg + 0.0346 Mz + 3.58 Eg \quad (3)$$

Since the coefficients of above forecasting model has been through the inspection, there is a long-term equilibrium correlation among $lnQg$, GDPg, Mz and Eg. From the perspective of long-term equilibrium, when the added-value of industry increases 1%, the electricity demand increase 0.9989%; when industrial proportion of heavy industry increase 1%, the electricity demand increases 0.03%; when electricity consumption intensity of industry increases 1%, the electricity demand increases 3.58%.

(3) The forecasting model of the construction industry electricity demand

The value-added of construction industry ($GDPj$), construction power efficiency (Ej) are the key factors affecting the electricity demand of the construction industry electricity demand (Qj) [17]. Therefore, based on the unit root test and co-integration test of these four factors, the forecasting model is established as follows:

$$\ln Qj = -4.8023 + 1.0272 \ln GDPj + 36.5440 Ej \quad (4)$$

Since the coefficients of above forecasting model has been through the inspection, there is a long-term equilibrium correlation among $lnQj$, $lnGDPj$ and Ej. From the perspective of long-term equilibrium, when the added-value of construction industry increases 1%, the electricity demand increases 1.027%; when construction power efficiency increases 1%, the electricity demand increases 36.54%.

(4) The forecasting model of the tertiary industry electricity demand

The value-added of the tertiary industry ($GDP3$), electricity consumption intensity of the tertiary industry ($E3$) are the key factors affecting the electricity demand of the

tertiary industry electricity demand ($Q3$) [18-19].Therefore, based on the unit root test and co-integration test of these four factors, the forecasting model is established as follows:

$$\ln Q3 = -3.9880 + 0.9991 \ln GDP3 + 19.2356 E3 \quad (5)$$

Since the coefficients of above forecasting model has been through the inspection, there is a long-term equilibrium correlation among $\ln Q3$ and $\ln GDP3$. From the perspective of long-term equilibrium, when the added-value of tertiary industry increases 1%, the electricity demand increases 0.999%; when construction power efficiency of tertiary industry increases 1%, the electricity demand increases 19.24%.

(5) The forecasting model of the resident sector electricity demand

The GDP per capita ($RJGDP$) is the key factors affecting the electricity demand of the resident sector electricity demand（Qp）[20-21]. Therefore, based on the unit root test and co-integration test of these four factors, the forecasting model is established as follows:

$$\ln Qp = -5.7894 + 1.1482 \ln RJGDP \quad (6)$$

Since the coefficients of above forecasting model has been through the inspection, there is a long-term equilibrium correlation among $\ln Qp$ and $\ln RJGDP$. From the perspective of long-term equilibrium, when the GDP per capita increases 1%, the electricity demand of resident sector increases 1.15%.

4. Forecasting the Electricity Demand of Each Sector in Hebei Province

4.1. The Development Situation of Each Influencing Factors

According to the development planning of different sectors, the situation of each influencing factors during the 13th Five-Year-Plan are shown as follows:

(1) The first industry

According to the planning of economy and structure development in Hebei province, the development situation of the first industry is divided into high and low situations, which are shown in the Table 1.

Table 1. The Development Situations of the First Industry

Year	Proportion of the first industry added-value	Added-value of high situation (One hundred million yuan)	Added-value of low situation (One hundred million yuan)
2015	9.57%	2148.106	2148.106
2016	9.08%	2170.597	2160.407
2017	9.08%	2311.686	2290.031
2018	9.08%	2461.946	2427.433
2019	9.08%	2621.972	2573.079
2020	9.08%	2792.401	2727.464

(2) The industry

According to the relative development planning of industry in Hebei province, the proportion of the industry added-value and the added-value of industry are divided into high and low situations, which are shown in the Table 2.

Table 2. The Development Situations of the Industry

Year	Proportion of the industry added-value	Added-value of high situation （One hundred million yuan）	Added-value of low situation （One hundred million yuan）
2015	89.25%	10317.14	10317.14
2016	89.25%	10462.9	10413.78
2017	89.25%	11142.99	11038.61
2018	89.25%	11867.28	11700.92
2019	89.25%	12638.66	12402.98
2020	89.25%	13460.17	13147.16

(3) The construction industry

The added-value of construction industry equates the second industry added value minus the industrial output value. What's more, considering the construction electricity consumption intensity is very small, which has a small decline in space. Therefore, the construction electricity intensity development scenarios are set by Five-year rolling average method, which are shown in the Table 3.

Table 3. The Development Situations of the Construction Industry

Year	Construction electricity consumption intensity (kWh/ten thousand yuan)	Added-value of high situation （One hundred million yuan）	Added-value of low situation （One hundred million yuan）
2015	284.5386	1242.681	1242.681
2016	288.6593	1260.237	1254.321
2017	283.5056	1342.153	1329.58
2018	278.5425	1429.393	1409.355
2019	281.5855	1522.303	1493.916
2020	283.3663	1621.253	1583.551

(4) The tertiary industry

According to the development planning related to the tertiary industry, the added-value is set with two scenarios. On the other hand, What's more, considering the electricity consumption intensity of the tertiary industry is very small, which has a small decline in space. Therefore, the electricity consumption intensity of the tertiary industry development scenarios are set by five-year rolling average method, which are shown in the Table 3.

Table 4. The Development Situations of the Tertiary Industry

Year	Proportion of the tertiary industry added-value	Added-value of high situation （One hundred million yuan）	Added-value of low situation （One hundred million yuan）
2015	38.93%	8738.33	8738.33
2016	41.88%	10011.52	9964.52
2017	41.88%	10662.27	10562.39
2018	41.88%	11355.32	11196.13
2019	41.88%	12093.41	11867.90
2020	41.88%	12879.49	12579.98

(5) The resident sector

The development of per capita GDP in Hebei province in the future is divided into high and low scenarios, which are shown in the Table 5.

Table 5. The Development Situations of the Resident Sector

Year	Per capita GDP of high situation (One hundred million yuan)	Per capita GDP of low situation (One hundred million yuan))
2015	30184.32	30184.32
2016	31918.72	31768.86
2017	33752.77	33436.59
2018	35692.22	35191.87
2019	37743.11	37039.29
2020	39911.84	38983.69

4.2. The Forecasting Results of Electricity Demand in Each Sector.

According to each industry and residents electricity consumption forecasting model, and the development situations, the various industries and residential electricity demand are calculated. The detail results are shown in the table6.

Table 6. Prediction Results of Added-value and Electricity Demand of Each Section in Hebei Province

Scenarios	2015		2020		Average annual growth rate during 13th Five-year	
	Low development speed	High development speed	Low development speed	High development speed	Low development speed	High development speed
Added-value (One hundred million yuan)						
First industry	2148	2148	2727	2792	2.71%	3.12%
Industry	10317	10317	13147	13460	4.95%	5.37%
Construction industry	1243	1243	1584	1621	5.80%	6.21%
Tertiary industry	8738	8738	12580	12879	8.72%	9.15%
GDP	22446	22446	30038	30753	6.18%	6.59%
Electricity demand (million kWh)						
First industry	140	140	174	177	1.67%	2.05%
industry	2537	2537	2844	2912	2.27%	2.67%
Construction industry	35	35	45	46	6.70%	7.12%
Tertiary industry	344	344	499	511	9.26%	9.69%
Residents demand	426	426	571	587	6.24%	6.72%
Whole society electricity demand	3482	3482	4134	4234	3.46%	3.87%

Table 7. Prediction Results of Economic Structure and Electricity Demand Structure

Scenarios	2015		2020		Annual proportion during 13th Five-year	
	Low Development speed	High development speed	Low Development speed	High development speed	Low Development speed	High development speed
Proportion of industry added value in the GDP（%）						
First industry	9.57%	9.57%	9.08%	9.08%	9.16%	9.16%
industry	45.96%	45.96%	43.77%	43.77%	44.13%	44.13%
Construction industry	5.54%	5.54%	5.27%	5.27%	5.32%	5.32%
Tertiary industry	38.93%	38.93%	41.88%	41.88%	41.39%	41.39%
Proportion of industry electricity demand in the whole society demand（%）						
First industry	4.02%	4.02%	4.20%	4.19%	4.06%	4.06%
industry	72.85%	72.85%	68.81%	68.78%	70.35%	70.34%
Construction industry	1.01%	1.01%	1.08%	1.08%	1.04%	1.04%
Tertiary industry	9.88%	9.88%	12.08%	12.07%	11.39%	11.39%
Residents demand	12.24%	12.24%	13.83%	13.87%	13.16%	13.18%

5. Conclusion

There is a long period between construction and production of the electricity project. The accurate prediction of electricity demand can guide a scientific planning, investment and construction, which is meaningful to the economic development and life standard improvement. Therefore, in order to guarantee plentiful power reserve capacity during the 13th Five-year period, the electricity demand should be forecasted exactly.

What's more, considering the different influencing factors and mechanism among different sectors, the whole society electricity demand is divided into five sectors: the first industry, industry, construction, the tertiary industry and resident sectors. The forecasting framework in this paper can better control the prediction error and make the prediction more accurate. Meanwhile, the electricity consumption structure in the future can be analyzed in this paper.

According to the above results, the characters of whole society electricity demand from 2015-2020 can be drawn as follows:

(1) With the growth rate decline of industry, the whole electricity demand will grow with a middle-low speed.

Nearly two years, with the advance of de-capacity and the air pollution control planning, there are lots of energy-intensive industries will face corrective, closure, governance and other pressures. The decline of the new industrial scale results the growth rate decline of the industry in the short term. During the 13th Five-year, the growth rate of industry in Hebei province is 2.27%-2.67%, which is lower than the growth rate during the 10th -12th Five-year. Due to the characters of economic structure in Hebei province, the decline of growth of industry electricity demand will drop the growth rate of whole society electricity demand. In the 13th period, the whole electricity demand will grow with a middle-low speed, the annual growth rate will be 3.46%-3.87%.

(2) Affected by the economic structure adjustment, the electricity demand of the tertiary industry and resident sector will grow faster than other sectors.

The third industry development has been growing fast since 2008, which owning a higher growth rate than GDP. Obviously, the economic center gradually shifts to the tertiary industry in Hebei province. Meanwhile, the electricity demand growth rate of the tertiary industry will increase. The annual growth rate of the electricity demand of tertiary industry in the 13th Five-year period will be 8.72%-9.15%. What's more, along with the advance of urbanization and the improvement of people's living standards, the annual growth rate of the electricity demand of resident sector in the 13th Five-year period will be 6.24%-6.72%.

(3) The economic structure and electricity demand structure will change.

The electricity demand structure in the first four years of 12th Five-year period is the first industry (4.3%): industry (74%): construction industry (0.94%): the tertiary industry (8.52%): resident sector (11.25%). Accordingly, the electricity demand in the 2015 will change. The proportion of the first industry and industry will decline, while the proportion of the construction industry, resident sector and the tertiary industry will increase. The electricity demand proportion of the industry in the whole society demand in 2015 will reach 72.85%, which will decline 2%. Meanwhile, the proportion of the tertiary industry and resident sector will reach 9.88% and 12.24%, which will increase 1% respectively.

During the 13th Five-year period, the demand proportion of the first industry and industry will decline further, while the demand proportion of resident sector and the tertiary industry will increase significantly. Contrast the demand structure of the first four year during the 12th Five-year period, the demand proportion of industry will decline 5%. Nevertheless, the proportion of tertiary industry and resident sector will increase 3% and 2%, respectively. Therefore, the electricity demand of Hebei province in the period of 13th Five year will change significantly.

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