Research on the relationship between the cost of power cable project and the periodic change of macroeconomic index

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Abstract. Cable line engineering is an important part of the transmission network. With increased urban development and the improvement of transmission lines, the investment scale is expanding. HP filter that is improved using the multifractal detrended fluctuation algorithm is used to analyze the periodic characteristics between the comprehensive cost index and macroeconomic indicators. And through the comprehensive cost index to optimize the accuracy of sample data. It is found that the fluctuation inflection point of power cable engineering’s comprehensive cost index is 0.5-0.7 years slower than those of the CPI and PPI. This research conclusion provides theoretical support for optimizing the calculation method of the driving factors of power grid project costs, the scientific analysis of power grid project cost trends, and rational investment planning.

1. Introduction

With the development of social economy, the progress of power industry is very rapid, and the scale of transmission line construction is increasing day by day. As an important transmission line project, power cable project has the advantages of high transmission stability and small floor area. It has a good development prospect under the background of the growing urbanization process[1]. Therefore, it is of practical significance to study the relationship between power cable engineering cost and macroeconomy. Macroeconomic indicators show periodic fluctuations from the perspective of the fluctuation trend. The relationship between the fluctuation of power cable costs and the periodic fluctuation of macroeconomic indicators is the focus of this paper. In Phillips’s research, it is pointed out that HP filter analysis is a powerful tool for exploring the cyclical characteristics between business cycles and business activities, but this method will not remove the trend effect in the limit[2]. Sebastian-Florian asserts that after the Pearson correlation coefficient is used to determine the correlation, the HP filter can be used to analyze the periodic synchronization of the macroeconomic fluctuations of different economic entities [3]. Ji Ling and Niu Dongxiao studied the relationship between electricity consumption and the macroeconomy by using the HP filter to decompose the time series between electricity consumption and GDP. The conclusion of the periodic characteristics laid a foundation for the causality test [4].

The remainder of this paper is organized as follows. Section 2 briefly introduces the theoretical methods that are used in the empirical calculation. Section 3 completes the screening of the influencing factors of costs and calculates the comprehensive cost index of a power cable project based on actual
engineering data. The periodic characteristics of their changing trends are explored using the HP filter analysis method that eliminates the trend. Sections 4 draw the conclusions.

2. Materials and methods

2.1 Model building steps

This paper mainly studies the periodic characteristic between the cost of power cable and macroeconomic changes through the HP filter method. Using the principal component analysis to reduce the dimension of the original data, the corresponding principal component data are obtained and substituted for the pauta criterion abnormal data screening model. After eliminating the non-representative special projects, HP filter method is used to analyze the periodic characteristics between the power cable engineering and macroeconomic fluctuations. The model’s flow chart is shown in Figure 1.

![Figure 1. Process of Relevance Model Construction](image)

As shown in the above figure, the process of building the model mainly includes the following steps:

(1) The indicators that cause the fluctuation of power cable project costs are determined, the sample engineering data are collected, and the original data are cleaned up.

(2) Principal component analysis (PCA) is used to reduce the dimension of the preliminarily processed sample data, and anomalous project data, which are far beyond the average and not representative, are eliminated using the Pauta criterion anomalous data screening model.

(3) According to the calculation method of the project cost index, the power cable project is distinguished according to the voltage level, technical scheme, and construction method; the corresponding investment weight is determined; and the comprehensive cost index of the power cable project is calculated.

(4) Useing the HP filter method to analyze the periodic characteristics between the power cable engineering and macroeconomic fluctuations.

2.2 HP filtering method based on multifractal detrended fluctuation analysis

Multifractal detrended fluctuation analysis (MF-DFA) improves the detrended fluctuation analysis method. Before HP filtering analysis, the algorithm is used to remove the influence of the comprehensive cost index of power cable engineering and to judge whether the data sequence has obvious type characteristics. It ensures that the long-term evolutionary process follows a specific fluctuation and assumes that the sequence to be analyzed is \{x_i\} (i=1,2,3,...N), where N represents the number of samples. The steps of the multifractal detrended fluctuation analysis algorithm are shown below[5].

A new time series is constructed by calculating the cumulative deviation N times from the original data. Here, \(X_{\text{mean}}\) is the mean of the original sample and \(Y(i)\) is the newly generated time series..
\[ y(i) = \sum_{i=1}^{N} (x_i - x_{mean}), i = 1, 2, ..., N \]  

Equation (1)

\( Y(i) \) is divided into nonoverlapping and equal-length segments in the unit of step \( s \). In addition, in order to ensure the integrity of the data’s information, \( y(i) \) is segmented again using step \( s \) from the opposite direction. It is known that the number of intervals \( V \) is \( N = \text{Int}(N/s) \), where \( \text{Int}() \) is an integer. Finally, \( 2Ns \) data intervals can be obtained. Then, we fit the substitution function curve \( p_v(j) \) of each newly generated interval \( v(\text{v}=1,2, ..., 2Ns) \) based on the least squares method. The detrended sequence \( Z_v(j) \) with a different length \( s \) can be obtained by calculating the difference between \( y_v(i) \) and \( p_v(j) \).

\[ Z_v(j) = y_v(j) - p_v(j), j = 1, 2, ..., s \]  

Equation (2)

The residuals of the detrended sequence \( Z_v(j) \) are also calculated.

\[ F^2(s,v) = \frac{1}{s} \sum_{i=1}^{s} Z^2_v(j), v = 1, 2, ... 2Ns \]  

Equation (3)

Next, we calculate the q-order fluctuation function of the sequence.

\[ F_q(s) = \left\{ \frac{1}{2Ns} \sum_{v=1}^{2Ns} [F^2(s,v)]^{\eta/2} \right\}^{1/\eta} \]  

Equation (4)

When the order of \( q \) is fixed, \( F_q(s) \) is positively correlated with \( s \). The relationship between \( F_q(s) \) and \( s \) can be summarized by the quantitative relationship of the double logarithmic coordinates.

\[ F_q(s) \propto S^{h(q)} \]  

Equation (5)

Here, \( h(q) \) represents the Hurst exponent. For nonstationary time series, when \( h(q) > 0.5 \), the sequence has multifractal characteristics and follows a specific fluctuation in the long-term evolutionary process. Subsequently, HP filtering analysis is carried out on the premise of ensuring the stability of the periodic component sequence at a certain significance level [6].

When Hodrick and Prescott analyzed the postwar American economic period, they first proposed the HP filtering method [7]. It is assumed that \{\( Y_t \)\} is an economic time series with a trend component and fluctuation component, \{\( Y^T_t \)\} is the trend component, and \{\( Y^C_t \)\} is the fluctuation component.

\[ Y_t = Y^T_t + Y^C_t \]  

Equation (6)

In this formula, \( t = 1, 2, ... \). The trend component \{\( Y^T_t \)\} can be solved by formula (7):

\[ \min_{Y_t} \left\{ \sum_{t=1}^{T} \{(Y_t - Y^T_t)^2 + \lambda \{C(L) \times Y^T_t \} \} \right\} \]  

Equation (8)

In the formula, \( C(L) \) is a delay operator polynomial. The values of \( \lambda \) according to the frequency of the sample data are shown as followings:

\[
\begin{align*}
\lambda &= \begin{cases} 
100 & \text{Annual data} \\
1600 & \text{Quarterly data} \\
14400 & \text{Monthly data}
\end{cases}
\end{align*}
\]

Generally, HP filtering regards the economic period as a deviation of the macroeconomy from a slowly changing path, and so the trend series and the period series have the same unit of measurement.

3. Case study

3.1 Indicator screening and quantification

In this paper, 64 power cable projects in a certain area of China from 2012 to 2017 are selected as the object of the empirical calculation. The construction costs of power cables are divided into two parts: electrical installation and civil construction. This paper identifies the influencing factors of the two major cost modules of electrical installation and civil construction, and then summarizes the influencing factors of the overall costs. The identification process is shown in Table 1.
### Table 1. Cost Influencing Factor Table

| Indicator Attributes | Indicator Name                        | Number |
|----------------------|---------------------------------------|--------|
| Natural conditions   | Geology                               | X1     |
|                      | Terrain                               | X2     |
|                      | Landforms                             | X3     |
|                      | Cable folding length                  | X4     |
|                      | Cable Section                         | X5     |
|                      | Cable Wire Quantity                   | X6     |
|                      | Number of Cable Loops                 | X7     |
| Technical conditions | Number of Intermediate Joints          | X8     |
|                      | Number of Terminal Joints             | X9     |
|                      | Full length of construction project   | X10    |
|                      | Length of Civil Crossing Section      | X11    |
|                      | Section of Underground Pipe Gallery   | X12    |
|                      | Civil Construction Coefficient        | X13    |
| Equipment prices     | Cable price                           | X14    |
|                      | Intermediate Joint Price              | X15    |
|                      | Terminal Joint Price                  | X16    |

#### 3.2 Periodic characteristic analysis

Before using the HP filter analysis method to periodically analyze the comprehensive cost index of the power cable project that is highly correlated with the CPI, PPI and copper barycenter price (CBP), the analysis index should be logarithmized and smoothly processed. To expand the index data, the time series step should be adjusted to 0.5 years. The multifractal detrended fluctuation analysis is used to test the fluctuation of the long-term evolution of the sequence. The results are shown in Figure. 2.

![Figure 2. Logarithmic Fluctuations of the Sequences](image)

As shown in the figure above, the fluctuation inflection point of the power cable engineering comprehensive cost index without the influence of the trend slips to the right by one sequence step compared with the CPI and PPI, which is approximately 0.5-0.7 years. Compared with the CPI and PPI, the inflection point of copper’s center of gravity price fluctuation is 0.5 sequence steps in length, which is approximately 0.3-0.5 years. Subsequently, the stationarity test is carried out for each sequence based on this result, as shown in Table 2.

### Table 2. ADF test results

| Name  | ADF Value | Stationarity | Intercept Term | Significance |
|-------|-----------|--------------|----------------|--------------|
| CCI   | -3.65891  | smooth       | no             | 0.05         |
| CPI   | -2.31594  | smooth       | no             | 0.05         |
| PPI   | -2.05963  | smooth       | no             | 0.01         |
| CBP   | -1.98752  | smooth       | no             | 0.01         |
The results of the ADF test show that the copper barycenter price and the sequence of the PPI’s periodic components are stable at the significance level of 0.01, and the composite cost index and the sequence of the CPI’s periodic components are stable at the significance level of 0.05. According to the stationarity test results of each index’s periodic component series, HP filtering analysis can be carried out. The fluctuation amplitude of each index periodic component series is shown in Figure 8.

Figure 3. Range of fluctuation of each sequence

From the analysis of the HP filter period, the results of Figure 8 show that the component fluctuation amplitudes of the CPI and PPI are 160.02% and 121.58%, respectively, the component fluctuation amplitude of the comprehensive cost index of power cable engineering is 163.49%, and the fluctuation amplitude of the copper barycenter price is 165.75%.

4. Conclusion
The periodic characteristics are analyzed. It is found that the fluctuation inflection point of the power cable engineering comprehensive cost index is 0.5-0.7 years slower than those of the CPI and PPI. This result provides a theoretical basis for the future investment planning of power cable engineering. The future investment planning of power cable engineering can refer to the trend of the macro economy and the price trends of major raw materials. According to the analysis results of the periodic characteristics, the lowest cost value can be selected from the perspective of the whole life period to improve the investment efficiency.

Furthermore, by realizing that different investment plans, environments and infrastructures exist in countries and regions, power cable construction investment should focus on building engineering such as underground pipe racks. The correlation analysis and the periodic characteristic analysis results may be related to the differences. In our future research, we will use this model to measure the need to adjust and modify coefficients and research different areas with different levels of productivity.

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