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Empirical Study on Influencing Factors and Fluctuations Law of Energy Prices Based on Factor and Partial Least-square Regression Analysis

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Abstract: This paper studies the influencing factors and fluctuations law of energy prices based on factor and partial least-square regression analysis. Firstly, the energy prices mode is given from the angles of market supply and demand, and the model fully reflects the factors that affect energy prices. Secondly, the influencing factors of energy prices are divided into four main factors based on factor analysis: supply and demand factors (FAC-1), general commodity prices factors (FAC-2), economic development factors (FAC-3) and government monetary policy factors (FAC-4). Finally, the energy prices forecasting model is established based on partial least-square regression analysis. Empirical results demonstrate that the proposed model has significantly reduced the forecasting errors.

Keywords: energy prices; energy supply and demand; factor analysis; partial least squares analysis

1 Introduction

Energy is the prime mover, essential to life, health and economic welfare. Without it no work can be done, no products can be produced and no economy can exist. For these reasons, and others, the issues of energy demand-supply and energy prices have attracted a great deal of attention from various fields of researchers. RS Pindyck [1] examined the long-run behavior of oil, coal, and natural gas prices, using up to 127 years of data, and explained energy prices in structural terms, i.e. in terms of movements in supply and demand, and variables that determine supply and demand. Sanjeev Kumar Aggarwal et al. [2] presented a wavelet transform (WT) based neural network (NN) model to forecast prices profile in a deregulated electricity market, and studied the behavior of the wavelet domain constitutive series based on statistical analysis. Hodge, Tyler et al. [3] focused on the pricing behavior of five major power marketers in the California PX during 2000: Duke Energy Trading & Marketing, Reliant Energy Services, Dynegy Power Marketing, Enron Power Marketing, and Williams Energy Marketing & Trading. Their results indicate that Duke Energy and Reliant were exercising market power when pricing the wholesale electricity they sold in the California PX during 2000. No statistical evidence was uncovered to show that the smaller marketers-dynegy, Williams and, Enron-were setting prices at a level higher than those consistent with a competitive market. Paul H et al. [4-5] performed numerous unvaried tests for non-linearity and chaotic structure using prices data from the energy sector to resolve whether the sector's fundamentals or exogenous shocks drive these prices. Xun Zhang,K et al.[6]extended ensemble EMD(EEMD) to crude oil prices analysis, EEMD is a substantial improvement of EMD which can better separate the scales naturally by adding white noise series to the original time series and then treating the ensemble averages as the true intrinsic modes.Irene Henriques and Perry Sadorsky [7] develops and estimates a model of a company's energy prices exposure and presents evidence showing that increases in a company's environmental sustainability lowers its energy prices exposure.

From the above analysis, we can see that previous researches mainly explored the influence of energy prices by energy structures, technical change and management level, energy consumption structure, economic structure, energy prices prediction and so on[1-6]. The relationship among energy security issues, climate change and energy prices variability were discussed and found that energy security issues and climate change are likely to increase energy prices variability in

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Table 1: Energy prices impact factors

Target layer A	Criteria layer B		Index layer	Variable
Energy prices	Supply Factors	Quantity supplied	Total Energy Production	x_{sc}
			Energy imports	x_{in}
		Investment	Elasticity of energy production	x_{ep}
		Cost	Fuel prices index	x_{gm}
	Demand factors	Quantity demanded	Total Energy Consumption	x_{xf}
			Energy exports	x_{ck}
		Industrial structure	Contribution of secondary industry	x_{si}
		Demographic factors	The proportion of urban residents	x_{ct}
			Energy consumption per capita	x_{ri}
			Engel coefficient	x_{eg}
	Macroeconomic factors	Economic output	GDP index	x_{gd}
		Economic growth	Elasticity of energy consumption	x_{ec}
		General prices level	The consumer prices index (CPI)	x_{ci}
			Producer Prices Index (PPI)	x_{pi}
		Energy Efficiency	Energy consumption per unit of GDP	x_{nh}

Source: China Statistical Yearbook 2012.

the coming years [7-8]. Energy prices models have been developed as asset pricing models in commodity markets. Gibson and Schwartz [9] propose a two-factor model for crude oil in which the log of spot prices follows a normal process and the convenience yield follows a mean reverting process. Brennan[10] also models commodity spot prices and convenience yields as separate stochastic processes with a constant correlation. In these researches, more comprehensive research methods were used, mainly related to the regression analysis, statistical analysis, neural networks, fuzzy math and so on, and many valuable results have been found [11-13]. While these models work well to describe energy prices, supply and demand relationship of energy is not describe the relationship of volatility trends among oil, coal, and power prices. The previous researches have rarely systematic study of the influencing factors and fluctuations law of energy prices.

The remainder of this paper is organized as follows. Section 2 discuses the formation mechanism of energy prices and conducts the energy prices mode from the angles of market supply and demand. Section 3 analysis the influencing factors of energy prices based on factor analysis. Section 4 establishes the energy prices forecasting model based on partial least-square regression analysis. Section 5 concludes and offers the directions for our future research.

2 The formation mechanism of energy prices

2.1 Analysis of the affect factors of energy prices

With the deepening of market reforms in energy prices in China, more and more factors play a more pronounced effect in energy prices. Identify the main factors affecting energy prices and quantitative analysis of the extent of their effects which have important significance for the grasp of the variation of the energy market and the state department in charge of macro-control energy market. The previous researches show that many factors which affect energy prices. Currently, the researches have focused on discussion of the relationship between economic growth, energy demand and energy prices etc, and given the connection between them from a macro point of view. Compared with the previous researches, this study conducted a comprehensive analysis from macroeconomic and microeconomic. We combed the direct and indirect factors which impact on energy prices, the specific indicators are as follows in Tab.1.

2.2 Energy prices model under supply and demand perspective

2.2.1 Energy prices model under the influence of supply factors

The supply amount of energy E_s mainly depends on the capacity of energy production enterprises W, profitability R, and other factors in the market Q_s, functional form expressed as:

$$E_s = F(W, R, Q_s) \tag{1}$$

where the capacity of energy production enterprises W mainly depends on investment in energy production I, and profitability R mainly depends on energy prices E_p and the cost of energy production E_{pc}. Therefore, formula (1) can be expressed as:

$$E_s = F(I, E_p, E_{pc}, Q_s) \tag{2}$$

Formula (2) shows that there are close relationship between energy prices E_p, energy supply E_s, investment in energy production I, and the cost of energy production E_{pc}. From formula (2), we can get the energy prices model under the influence of supply factors:

$$E_p = G(X_1) = G(E_s, I, E_{pc}, Q_s) \tag{3}$$

where G is the inverse function of F.

2.2.2 Energy prices model under the influence of demand factors

In energy demand market, energy demand E_d mainly depends on energy prices E_p, energy efficiency E_{xl}, industrial structure CJ, population structure RJ, energy consumption capacity E_{xf}, macroeconomic environment H, and other external factors Q_d. Functional form expressed as:

$$E_d = F(E_p, E_{xl}, CJ, RJ, E_{xf}, H, Q_d) \tag{4}$$

Formula (4) shows that there are close relationship between energy prices E_p, energy demand E_d, energy efficiency E_{xl}, industrial structure CJ, population structure RJ, energy consumption capacity E_{xf},macroeconomic environment H, and other external factors Q_d. From formula (4), we can get the energy prices model under the influence of demand factors:

$$E_p = G(X_2) = G(E_d, E_{xl}, CJ, RJ, E_{xf}, H, Q_d) \tag{5}$$

2.2.3 Energy prices model under supply and demand equilibrium

The energy equilibrium prices were formed when the energy supply is equal to the energy demand, Functional form expressed as:

$$E_s = E_d \tag{6}$$

By (2)and(4) we have

$$F(I, E_p, E_{pc}, Q_s) = F(E_p, E_{xl}, CJ, RJ, E_{xf}, H, Q_d) \tag{7}$$

Formula (7) shows that there are relationship between energy prices and other external factors. Transformed by a certain functional relationship, we can get the energy prices model under supply and demand equilibrium:

$$E_p = G(X_3) = G(I, E_s, E_{pc}, Q_s, E_d, E_{xl}, CJ, RJ, E_{xf}, H, Q_d) \tag{8}$$

The linear expression of the formula (8) is show as follow:

$$E_p = \beta_0 + \Sigma\beta_i X_i + \varepsilon \tag{9}$$

That is

$$\begin{aligned} E_p = \beta_0 + \beta_1 x_{sc} + \beta_2 x_{in} + \beta_3 x_{ep} + \beta_4 x_{gm} + \beta_5 x_{xf} + \beta_6 x_{ck} + \beta_7 x_{si} \\ +\beta_8 x_{ct} + \beta_9 x_{ri} + \beta_{10} x_{eg} + \beta_{11} x_{gd} + \beta_{12} x_{ec} + \beta_{13} x_{ci} + \beta_{14} x_{pi} + \beta_{15} x_{nh} + \varepsilon_3 \end{aligned} \tag{10}$$

We will give the method for determining model parameters in the following based on partial least-square regression analysis.

Table 2: The correlation coefficient between the influencing factors of energy prices

	x_{sc}	x_{in}	x_{ep}	x_{gm}	x_{xf}	x_{ck}	x_{si}	x_{ct}	x_{ri}	x_{eg}	x_{gd}	x_{ec}	x_{ci}	x_{pi}
x_{sc}	1.00	0.98	0.22	0.11	0.99	0.68	0.51	0.97	0.94	-0.87	0.15	0.19	-0.51	-0.16
x_{in}	0.98	1.00	0.20	0.06	0.98	0.62	0.51	0.94	0.93	-0.86	0.13	0.17	-0.49	-0.24
x_{ep}	0.22	0.20	1.00	0.03	0.21	0.41	-0.02	0.22	0.22	-0.24	-0.10	0.82	0.00	0.18
x_{gm}	0.11	0.06	0.03	1.00	0.12	0.01	0.25	0.07	0.11	-0.02	0.35	0.08	0.28	0.70
x_{xf}	0.99	0.98	0.21	0.12	1.00	0.69	0.53	0.97	0.94	-0.88	0.16	0.18	-0.52	-0.16
x_{ck}	0.68	0.62	0.41	0.01	0.69	1.00	0.35	0.81	0.52	-0.88	0.09	0.46	-0.59	-0.21
x_{si}	0.51	0.51	-0.02	0.25	0.53	0.35	1.00	0.49	0.34	-0.53	0.15	-0.06	-0.14	-0.11
x_{ct}	0.97	0.94	0.22	0.07	0.97	0.81	0.49	1.00	0.85	-0.96	0.11	0.21	-0.64	-0.21
x_{ri}	0.94	0.93	0.22	0.11	0.94	0.52	0.34	0.85	1.00	-0.70	0.19	0.22	-0.40	-0.03
x_{eg}	-0.87	-0.86	-0.24	-0.02	-0.88	-0.88	-0.53	-0.96	-0.70	1.00	-0.10	-0.24	0.63	0.32
x_{gd}	0.15	0.13	-0.10	0.35	0.16	0.09	0.15	0.11	0.19	-0.10	1.00	0.00	0.38	0.28
x_{ec}	0.19	0.17	0.82	0.08	0.18	0.46	-0.06	0.21	0.22	-0.24	0.00	1.00	-0.06	0.16
x_{ci}	-0.51	-0.49	0.00	0.28	-0.52	-0.59	-0.14	-0.64	-0.40	0.63	0.38	-0.06	1.00	0.44
x_{pi}	-0.16	-0.24	0.18	0.70	-0.16	-0.21	-0.11	-0.21	-0.03	0.32	0.28	0.16	0.44	1.00

3 Analysis of the influencing factors of energy prices based on factor analysis

3.1 Methodology

Factor analysis [16] is a collection of methods used to examine how underlying constructs influence the responses on a number of measured variables. Factor analysis model can be can be described as follow: Let variable $X_i, (i = 1, 2, \cdots, p)$ be expressed as

$$X_i = \mu_i + \alpha_{i1}F_1 + \cdots + \alpha_{im}F_m + \varepsilon_i, m \le p$$

Expressed in matrix form

$$\mathbf{X} - \mu = \Lambda\mathbf{F} + \varepsilon$$

where

$$\mathbf{X} = \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_p \end{pmatrix}, \mu = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_p \end{pmatrix}, \Lambda = \begin{pmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1m} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ \alpha_{p1} & \alpha_{p2} & \cdots & \alpha_{pm} \end{pmatrix}, \mathbf{F} = \begin{pmatrix} F_1 \\ F_2 \\ \vdots \\ F_p \end{pmatrix}, \varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_p \end{pmatrix},$$

where, $F_1, F_2, \cdots, F_p$ are common factors which are unobservable variables. Their coefficients are load factors. ε_i are special factors , which can not be included in the previous part of common factors , and they satisfies:

$$E(\mathbf{F}) = 0, E(\varepsilon) = 0, Cov(\mathbf{F}) = I_m,$$

$$D(\varepsilon) = Cov(\varepsilon) = diag(\sigma_1^2, \sigma_2^2, \cdots, \sigma_m^2), Cov(\mathbf{F}, \varepsilon) = 0.$$

3.2 Empirical analysis

To eliminate various indicators dimensionless, we firstly convert each index value x_{ij} in $Tab1$ into the standardized index value $\overline{x_{ij}}$ and calculate the correlation coefficient matrix. The calculation results are shown in Tab.2.

From Tab.2, we can see that there is the high degree of positive correlation among total energy production, energy imports, energy consumption, energy exports, the proportion of the urban population and per capita energy consumption, the correlation coefficients are 0.98, 0.99, 0.68, 0.97, 0.94, respectively. There is the high degree of negative correlation between total energy production, Engel coefficient and energy consumption per unit of GDP, the correlation coefficients are -0.87, -0.72, respectively. There is the high degree of positive correlation between the elasticity coefficient of energy production and the elasticity coefficient of energy consumption, the correlation coefficient is 0.82. There is the high degree of positive correlation between fuel prices index and the producer prices index (PPI), the correlation coefficient is 0.7. There is the high degree of positive correlation among the consumer prices index (CPI), the proportion of urban

Table 3: Statistical properties of the factor loadings matrix

Factor	Factors contribution	Contribution	Cumulative contribution	Common degree	Special variance
Factor 1	7.6000	50.6666	50.6666	0.9929	0.0071
Factor 2	2.2891	15.2604	65.9270	0.9746	0.0254
Factor 3	1.8951	12.6340	78.5610	0.8981	0.1019
Factor 4	0.9873	6.5820	85.1430	0.8518	0.1482
Factor 5	0.7876	5.2507	90.3937	0.9939	0.0061
Factor 6	0.7357	4.9046	95.2983	0.8976	0.1024
Factor 7	0.2602	1.7347	97.0330	0.7208	0.2792
Factor 8	0.2051	1.3674	98.4004	0.9940	0.0060
Factor 9	0.1181	0.7873	99.1877	0.9816	0.0184
Factor 10	0.0657	0.4378	99.6264	0.9601	0.0399
Factor 11	0.0444	0.2959	99.9223	0.7672	0.3328
Factor 12	0.0090	0.0601	99.9824	0.9125	0.0875
Factor 13	0.0018	0.0120	99.9944	0.8897	0.1103
Factor 14	0.0008	0.0054	99.9998	0.9187	0.0813
Factor 15	0.0002	0.0013	100	0.9055	0.0945

residents, Engel coefficient and the energy consumption per unit of GDP, the correlation coefficients are -0.64,0.63,0.61, respectively.

From above analysis, it is found that there are multiple correlations among all the impact factors. The correlation coefficients among some indicators are more than 0.9. Therefore, we can select some common factors to conduct a comprehensive analysis of all these variables.

Let $\lambda_1, \lambda_2, \cdots, \lambda_p$ be the eigenvalues of the correlation coefficient matrix R, $u_1, u_2, \cdots, u_p$ be the corresponding eigenvectors, where $u_j = (u_{1j}, u_{2,j}, \cdots, u_{nj})^T$, then the elementary loading matrix denote as

$$A = [\sqrt{\lambda_1}u_1, \sqrt{\lambda_2}u_2, \cdots, \sqrt{\lambda_p}u_p]$$

The elements of the elementary loading matrix denote as a_{ij}, variables common degree denote as $h_i^2 = \sum_{j=1}^{m} a_{ij}^2$, special factor variance denote as δ_i^2,where

$$\delta_i^2 = 1 - \sum_{j=1}^{m} a_{ij}^2$$

The calculation results of various public factors are shown in Tab.3.

From Tab.3, it is found that cumulative contribution rate of the previous four public factors reach to 85.143% . Therefore, the previous four main ingredients are able to reflect the majority of all data information. So, it is feasible to take four public factors as the main factors. Analyzed by four common factors, the calculate results of the special variance and the common degree are show in Tab.3, it is found that the minimum value of common degree is 0.7208, and the mean of common degree is 0.9106. Therefore, all the factors can be explained by the four public factors.

In order to explain the actual significance of the public factor, we rotate the elementary load matrix. The rotated elementary load matrix denote as $B = AT$, where $T$is orthogonal matrix.The calculation results of the elementary load matrix before and after the rotation are shown in Tab.4.

From Tab.4, it is found that load factor has been significantly polarization after the rotation of the elementary load matrix. According to the score value of the four main ingredients in each year from 1980 to 2010, the fluctuating trend graph of the four main ingredients and energy prices is showed in Fig.1(a,b,c,d).

From Tab.3 and Tab.4, it is found that the contribution rate of the first main component is 50.6666%. The factor reflect and impact energy prices from the two levels of energy supply and energy demand, respectively. Therefore, the first principal component can be interpreted as a factor of supply and demand factors which affecting energy prices. From Fig.1(a), it is found that there is the closest fluctuating trend between the first principal component and energy prices, from $Tab4$, the relational grade is 0.8727, which show that the first principal component can more accurately reflect the volatility of energy prices trend, that is, energy supply and demand has a very significant impact on energy prices.

The contribution rate of the second main component is 15.2604%. The factor can be interpreted as a factor of general commodity prices factor which affecting energy prices. From Fig.1(b), it is found that there is the close fluctuating trend between the second principal component and energy prices, the relational grade is 0.7041, which show that the second

Table 4: Elementary loading matrix of the four main factors

Index	F_1	F_2	F_3	F_4	$T^T F_1$	$T^T F_2$	$T^T F_3$	$T^T F_4$
x_{sc}	0.9691	0.0528	-0.0913	0.1360	0.9776	-0.0140	0.1091	-0.0298
x_{in}	0.9400	-0.0020	-0.0971	0.2326	0.9620	-0.1086	0.0948	0.0320
x_{ep}	0.2712	0.3254	0.8405	0.1023	0.1175	0.0454	0.9381	-0.0198
x_{gm}	0.0871	0.8137	-0.2602	-0.3374	0.1271	0.9022	-0.0190	0.1441
x_{xf}	0.9720	0.0518	-0.1054	0.1260	0.9819	-0.0067	0.0948	-0.0356
x_{ck}	0.8249	-0.0139	0.2868	-0.1913	0.7105	0.0268	0.3711	-0.3953
x_{si}	0.5275	0.1094	-0.3533	0.1022	0.6027	0.1055	-0.1930	0.1180
x_{ct}	0.9949	-0.0284	-0.0400	-0.0242	0.9656	-0.0078	0.1141	-0.2178
x_{ri}	0.8606	0.1379	-0.0616	0.2488	0.8864	-0.0080	0.1604	0.1174
x_{eg}	-0.9545	0.0935	-0.0133	0.0416	-0.9101	0.0631	-0.1343	0.2674
x_{gd}	0.1140	0.5775	-0.3641	0.3775	0.2653	0.3531	-0.0884	0.6470
x_{ec}	0.2652	0.3447	0.8401	0.0837	0.1100	0.0713	0.9402	-0.0250
x_{ci}	-0.6254	0.5520	-0.1005	0.4204	-0.4992	0.2603	0.0324	0.7514
x_{pi}	-0.2050	0.8444	-0.0145	-0.3202	-0.2024	0.8707	0.1725	0.1703
x_{nh}	-0.7967	-0.0688	0.1758	0.4842	-0.7411	-0.3418	0.0757	0.4827

Figure 1: The fluctuating trend graph of the four main ingredients

main component and energy prices are related to each other. However, the fluctuation of the second principal component is bigger than the fluctuation of energy prices, and the fluctuations trend of the second principal component has a significant lag which show that prices fluctuations of production areas has a certain lag relative to energy prices.

The contribution rate of the third main component is 12.634%. The factor mainly reflects the relationship between the growth rate of energy production and consumption and the growth rate of the national economy on energy prices. Therefore, the third principal component can be interpreted as a factor of economic development factor which affecting energy prices. From Fig.1(c), it is found that there is the differences larger fluctuating trend between the third principal component and energy prices, the relational grade is 0.6275, which shows low correlation between the third principal component and energy prices. From Fig.1(c), it is found that the third principal component and energy prices appear consistent fluctuation trend in a period of time, but another time period will appear opposite fluctuations trend, for example, during 1990 to 1993, energy prices show an upward trend, however the third main component show a downward trend which show that it can not simply measure the level of energy prices from the level of economic development

The contribution rate of the fourth main component is 6.582%. The factor mainly reflect the market economy and the government's monetary policy. Therefore, the fourth principal component can be interpreted as a factor of government monetary policy factors which affecting energy prices. The relational grade is 0.7451, which show that the fourth main component and energy prices are related to each other. However, From Fig.1(d), it is found that the fluctuating trend of the fourth main component relatively flat which show that from the Chinese realistic situation of economic operation, stability and its importance in the CPI index is not as mature economies countries. The market economy will not be adjusted according to changes in the CPI.

4 Fluctuations law of energy prices based on PLS analysis

4.1 Methodology

Partial least squares (PLS) regression is a widely used multivariate regression technique. This projection method is used to extract the information contained in available process data, and to project it onto to a low-dimensional space defined by new variables called latent variables [17]

Let X is independent variables, Y is dependent variables, E_0 is standardized variables of independent variables X, F_0 is standardized variables of dependent variables,

$$E_0 = \begin{pmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & & \vdots \\ x_{n1} & \cdots & x_{nm} \end{pmatrix}, F_0 = \begin{pmatrix} y_{11} & \cdots & y_{1p} \\ \vdots & & \vdots \\ y_{n1} & \cdots & y_{np} \end{pmatrix}$$

We give the simple steps of the Partial least squares regression model as follows:

Step1: Compute maximum eigenvalue of the corresponding eigenvector ω_1 of matrix $E_0^T F_0 F_0^T E_0$, compute component scores vector $\hat{t_1} = E_0\omega_1$ and residual matrix $E_1 = E_0 - \hat{t_1}\alpha_1^T$, where $\alpha_1 = E_0^T \hat{t_1} / \parallel \hat{t_1} \parallel^2$.

Step2: Compute maximum eigenvalue of the corresponding eigenvector ω_2 of matrix $E_1^T F_0 F_0^T E_1$, compute component scores vector $\hat{t_2} = E_1\omega_2$ and residual matrix $E_2 = E_1 - t_1\alpha_2^T$, where $\alpha_2 = E_1^T \hat{t_2} / \parallel \hat{t_2} \parallel^2$.Repeating the above step in the same way, go to the $r-$step, compute maximum eigenvalue of the corresponding eigenvector ω_r of matrix $E_{r-1}^T F_0 F_0^T E_{r-1}$, compute component scores vector$_r^t = E_{r-1}\omega_r$.

Step3: Cross usefulness principle, define cross usefulness

$$Q_h^2 = 1 - PRESS(h)/SS(h-1)$$

where,$PRESS(h) = \sum_{i=1}^{p} PRESS_j(h), SS(h) = \sum_{j=1}^{p} SS_j(h)$. Set the limit value is 0.05, when the end of each step of the calculation, compute the value of Q_h^2. If in the h-th step,$Q_h^2 < 1 - 0.95^2 = 0.0985$, then model achieve the accuracy requirements,$h$is the required number of components.

Step4: reconstructing Partial Least Squares regression model

$$\underset{0}{F} = r_1 t_1 + r_2 t_2 + \cdots + r_n t_h \tag{11}$$

where

$$t_i = E_{i-1}W_i = E_0 W_i^*, W_i^* = \prod_{k=1}^{i-1}(i - W_k P_k^T)W_i, \tag{12}$$

Table 5: The contribution rate of the independent variables and the dependent variable

independent variables	0.2451	0.3396	0.0651	0.0626	0.1033	0.0347	$\cdots$
dependent variable	0.6903	0.0222	0.0808	0.0464	0.0142	0.0195	$\cdots$

$P_k$is regression coefficient. Simultaneous equations (16)and(17) , obtained

$$ {}_0^F = r_1 E_0 W_1^* + r_2 E_0 W_2^* + \cdots + r_h E_0 W_h^* \tag{13}$$

Denoting

$$y^* = F_0, x_i^* = E_{0i}, \alpha_i = \sum_{k=1}^{h} r_k W_{ki}^* \tag{14}$$

Standardized regression equation is

$$y^* = \alpha_1 x_1^* + \alpha_2^* + \cdots + \alpha_m x_m^* \tag{15}$$

4.2 Empirical analysis on fluctuations law of energy prices

To eliminate various indicators dimensionless, we firstly convert each index value in Tab.1 into the standardized index value and calculate the correlation coefficient matrix. According to the correlation matrix, we calculate the contribution rate of the independent variables and the dependent variable. The calculation results are shown in Tab.5.

From Tab.5,it is found that the cumulative contribution rate of the previous six public factors of independent variables and dependent variable reach to 85.04% and 87.34%, respectively. So, it is feasible to take six public factors as the main factors, denote as $u_1, u_2, \cdots, u_6$. Therefore, main factors regression equations are shown below:

$$\begin{cases} \overline{x}_{coal} = 4.677u_1 - 0.1559u_2 - 1.35u_3 - 0.6159u_4 - 0.7495u_5 + 1.0898u_6 \\ \overline{x}_{power} = 4.4442u_1 + 1.7136u_2 + 0.388u_3 - 1.562u_4 + 0.5015u_5 - 0.5701u_6 \\ \vdots \\ \overline{y}_{oil} = 4.5506u_1 + 0.816u_2 + 1.5574u_3 + 1.1796u_4 + 0.653u_5 + 0.7655u_6 \end{cases}$$

Standardized variables regression equation is shown below:

$$\begin{aligned} \overline{y}_{oil} &= -0.31\overline{x}_{coal} + 0.0671\overline{x}_{power} + 0.0176\overline{x}_{sx} - 0.1388\overline{x}_{ep} + 0.9478\overline{x}_{gm} \\ &+0.1957\overline{x}_{ic} - 0.1166\overline{x}_{si} + 0.1249\overline{x}_{ct} - 0.2226\overline{x}_{ri} - 0.5619\overline{x}_{eg} + 0.0186\overline{x}_{gd} \\ &-0.0738\overline{x}_{ec} - 0.0508\overline{x}_{ci} + 0.4357\overline{x}_{pi} + 0.2543\overline{x}_{nh} \end{aligned} \tag{16}$$

In order to observe the marginal effect of each independent variable on the dependent variable, according to the standardized variables regression equation, we draw the regression coefficient map which is shown in Fig.2(a).

From Fig.2(a), it is found that fuel prices index, Engel coefficient and producer prices index have a very significant effect on oil prices. Fuel prices index has the most significant effect on oil prices, the influence coefficient is 0.9478. From Fig.2(a), it is also found that the total indicators were divided into positive indicators and negative indicators. The positive indicators consist of eight indicators: power prices (x_{power}), energy production and consumption ratio (x_{pc}), fuel prices index (x_{gm}), energy import and export ratio (x_{ic}), the proportion of urban residents (x_{ct}), GDP index (x_{gd}), producer prices index (PPI) (x_{pi}), and energy consumption per unit of GDP (x_{nh}). The negative indicators consist of seven indicators: coal prices (x_{coal}), the elasticity coefficient of energy production (x_{ep}), the elasticity coefficient of energy consumption (x_{ec}), the contribution rate of the secondary industry (x_{si}), energy consumption per capita (x_{ri}), Engel coefficient (x_{eg}), and the consumer prices index (CPI) (x_{ci}).

Standardized variables were restored to the original variables, original variables regression equation is shown below:

$$\begin{aligned} y_{oil} &= -51.3763 - 0.5375x_{coal} + 0.1227x_{power} + 3.9606x_{sx} - 6.3341x_{ep} + 1.9568x_{gm} + 0.6563x_{ic} \\ &-105.3692x_{si} + 0.2344x_{ct} - 0.0843x_{ri} - 1.2493x_{eg} + 0.1137x_{gd} - 3.8865x_{ec} - 0.1208x_{ci} \\ &+1.064x_{pi} + 1.0539x_{nh} \end{aligned} \tag{17}$$

Using the model to predict oil prices, the calculation results are shown in Fig.2(b). From Fig.2(b), it is found that the model has higher prediction accuracy. Therefore, it is feasible to use partial least squares regression model predict oil prices.

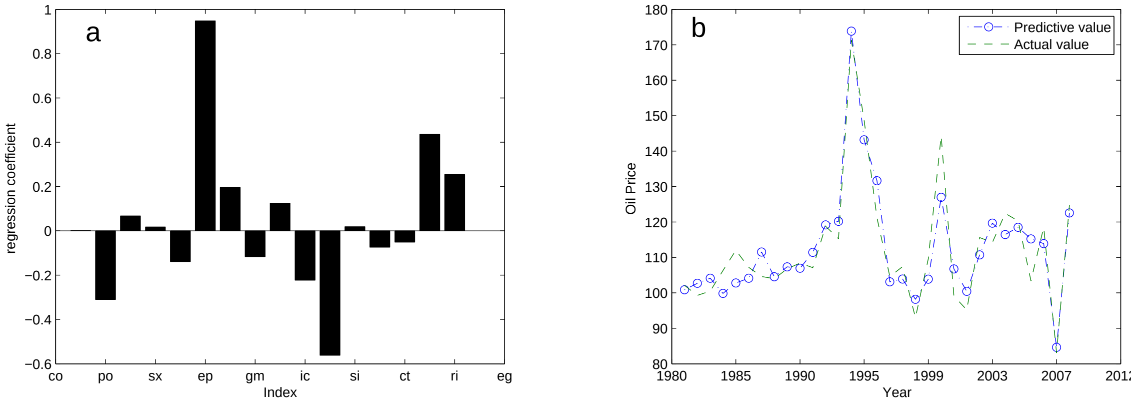

Figure 2: (a)The regression coefficient map;(b)Predictive value and actual value of oil prices

Table 6: Accuracy of the model

	α	ε_0	C_0	p_0
Oil prices	0.0425	0.9456	0.3558	1
Power prices	0.0270	0.9258	0.4634	1
Coal prices	0.0297	0.9243	0.4942	1

Similarly, regression equations of power prices and coal prices are shown below, and the predictive effect diagram is shown in Fig.3(a,b). Accuracy of the model Predictive results are shown in Tab.6.

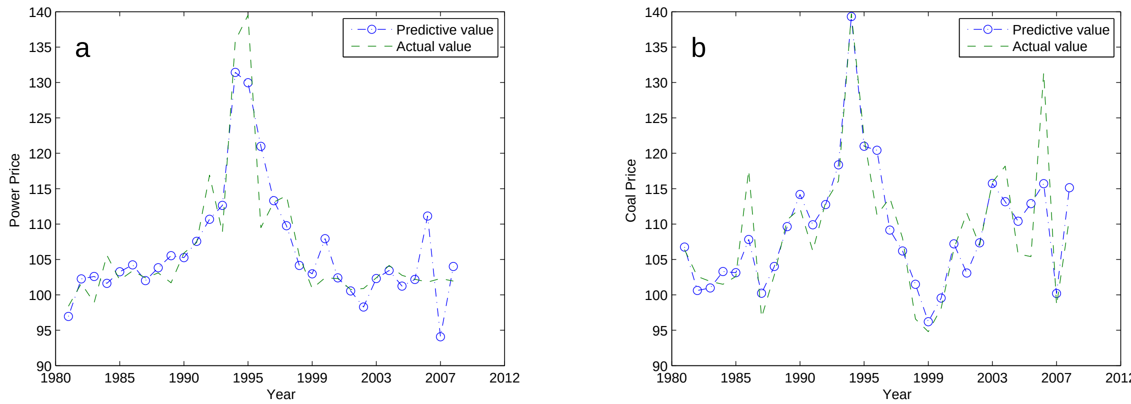

Figure 3: Predictive value and actual value of power and coal prices

5 Conclusions

The purpose of this study is to test the relationship among the elasticity coefficient of energy production (x_{ep}) ,the elasticity coefficient of energy consumption (x_{ec}), the total energy production (x_{sc}), energy imports (x_{in}), the contribution rate of the secondary industry (x_{si}), the proportion of urban residents (x_{ct}), total energy consumption (x_{xf}), energy exports (x_{ck}), energy consumption per capita (x_{ri}), energy consumption per unit of GDP (x_{nh}), Engel coefficient (x_{eg}), the consumer prices index (CPI) (x_{ci}), fuel prices index (x_{gm}), GDP index (x_{gd}) ,producer prices index (PPI) (x_{pi}) and energy prices. The results show that a variety of factors may have an impact on energy prices. Therefore, when the relevant departments formulate the energy strategy, the market supply and demand, population structure, industrial structure and monetary policy must be comprehensive considered.

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