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Analysis of the Energy Evolution Process of Four US States Based on Economics

Wenbing Dong

Anhui University of Finance & Economics, School of Economics, China

Abstract: Based on energy consumption data from 1960 to 2009 in California, Arizona, New Mexico, and Texas, we created an energy profile for four states. Then we built a RBF Neural Network Model to analyze the energy development profiles of the four states. Finally, we gave relevant recommendations based on economic theory.

Keywords: RBF Neural Network Model, Multi-Objective Programming Model, Renewable Energy.

1. ENERGY PROFILE FOR EACH OF THE FOUR STATES

1.1 Problem analysis.

Based on the data provided, we will create an energy summary for California, Arizona, New Mexico, and Texas. From the perspective of energy consumption, we first of all, according to the U.S. energy information administration (EIA) for the classification of energy fuels, filtered to provide data processing, sorting out of the states in 2009 the proportion of main types of fuel consumption. Then, based on the classification of the department, we calculated the fuel consumption of each department, and thus got four states of energy summarization.

1.2 The solution to this problem.

According to the latest energy classification on the U.S. energy information administration's website, we treat the data as follows, that is, the fuel types are divided into oil, coal, natural gas, renewable energy, clean energy, and other fuels. In addition, we summarized the various fuels in 2009 and calculated the proportion of various forms of fuel consumption in the four states of CA, AZ, NM and TX respectively. As shown below.

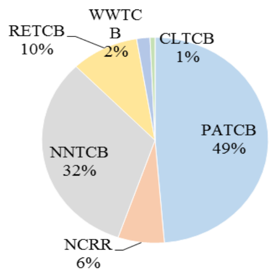

Fig 1. Primary Consumption of Energy in CA

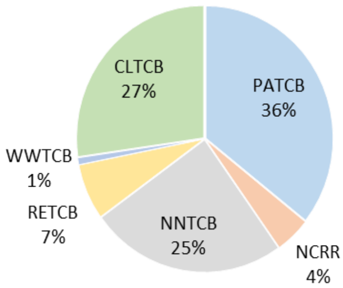

Fig 2. Primary Consumption of Energy in AZ

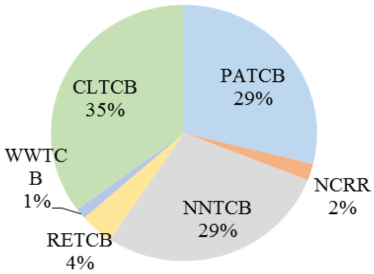

Fig 3. Primary Consumption of Energy in NM

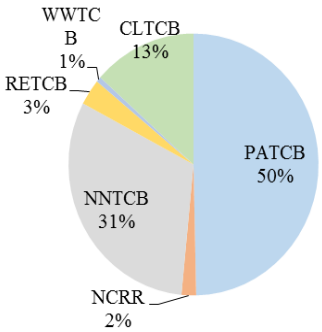

Fig 4. Primary Consumption of Energy in TX

California (CA) 2009 energy consumption is summarized as follows: all accounted for 49% of the total consumption of petroleum products, coal consumption accounted for 1%, total renewable energy consumption by 10%, total gas consumption (excluding the supplementary fuel gas) accounted for 32%, clean energy consumption accounted for 6%, other 2% of the total energy consumption accounted.

Arizona (AZ) 2009 energy consumption is summarized as follows: all accounted for 36% of the total consumption of petroleum products, coal consumption accounted for 27%, total renewable energy consumption by 7%, total gas consumption (excluding the supplementary fuel gas) accounted for 25%, clean energy consumption accounted for 4%, other 1% of the total energy consumption accounted.

Energy consumption in 2009 in New Mexico summarized as follows: all accounted for 29% of the total consumption of petroleum products, coal consumption accounted for 35%, total renewable energy consumption by 4%, total gas consumption (excluding the supplementary fuel gas) accounted for 29%, clean energy consumption accounted for 2%, other 1% of the total energy consumption accounted.

Energy consumption in 2009, Texas summarized as follows: all accounted for 50% of the total consumption of petroleum products, coal consumption accounted for 13%, total renewable energy consumption by 3%, total gas consumption (excluding the supplementary fuel gas) accounted for 31%, clean energy consumption accounted for 2%, other 1% of the total energy consumption accounted.

On the basis of the above fuel classification, we have also made statistics on the consumption of fuel in each of the four states. Table 1 shows the state of fuel consumption in various parts of California. Fuel consumption in various parts of Arizona, New Mexico and Texas is shown in Table 1.

Tab 1. Department fuel consumption status

	Residential Btu	Commercial Btu	Industrial Btu	Transportation Btu	Net Consumption Btu
Coal	0	0	31318.47	0	31318.47
Natural Gas	493593.99	254251.92	19952.36	19952.36	787750.63
Petroleum Products					
Distillate	2320.12	22615.50	61774.32	439280.67	525990.60
Residual		0	6.65		6.65
Kerosene	977.01	107.21		555575.44	556659.66
Gasoline	0	1404.64	87.47	1846996.94	1848314.11
Jet Fuel	-	-	-	555575.44	555575.44
Renewable Resources					712704.46
Electric Sales	306393.29	413211.65	163213.54	2880.85	885699.32
Other	25971.95	4290.31	23070.59	-	53332.85
Net Consumption	829256.35	695881.22	299248.45	3420261.7	5244647.72

In California, the net fuel consumption of the residential sector is 829256.35Btu, the net fuel consumption of the commercial sector is 695881.22Btu, the net fuel consumption of the industrial sector is 299248.45Btu, and the net fuel consumption of the transportation department is 3420261.7Btu.

In Arizona, the net fuel consumption of the household sector is 155832.13Btu, the net fuel consumption of the commercial sector is 140259.08Btu, the net fuel consumption of the industrial sector is 97753.72Btu, and the net fuel consumption of the transportation department is 523635.34Btu.

The net fuel consumption of New Mexico is 64505.79Btu, the net fuel consumption of the commercial sector is 58419.49Btu, the net fuel consumption of the industrial sector is 43914.17Btu, and the net fuel consumption of the transportation sector is 208849.13Btu.

Texas has a net fuel consumption of 658281.96Btu, and the commercial sector's net fuel consumption is 601279.31Btu. The net fuel consumption of the industrial sector is 604401.07Btu, and the net fuel consumption of the transport sector is 2921525.42Btu.

1.3 Model-based establishment —an overview of energy development in four states from 1960 to 2009.

1.3.1 Problem analysis.

The problem required us to establish a model to describe the evolution of energy profiles in the four states of 1960-2009 and to analyze the results to address the use of renewable energy in the four states while applying the geography, climate, Demographic, and industrial differences to explain the different causes of energy profiles in the four states. To address this issue, firstly, we collect data on topography, climate, industrial output, state GDP, and population in each of the four states. Then, we build a gray relational model to observe the correlation between each variable and each state's energy use, and select the variables with higher correlation. At last, we establish a RBF neural network model to fit the principle of energy profile changes. We hope that through continuous training model, we can find out the evolution model that best fits the situation of each state and use the graph to show the evolution of energy profile.

1.3.2 Model preparation.

When analyzing the five indicators of geography, climate, industry, population and GDP in the four states, we find that geography and climate are unchanged from year to year, while industry, population and GDP change over time. Based on our experience and literature review, we can easily find out that geography and climate have an impact on the industry, population and GDP of the region over many years of development. Therefore, when we prove that industry, population and GDP had an impact on energy evolution, at the same time, it can be proved that geography and climate also have an indirect impact on energy evolution. In addition, the temperature level, the amount of rainfall, geographical differences, also have a direct impact on energy evolution. Due to the limited time, we only make theoretical explanations for this.

We search data on the geography, climate, industry, population and GDP of the four states from 1960 to 2009 at the U.S. Federal Statistical Office, the U.S. Energy Information Administration and the U.S. National Climatic Data Center. Due to the large time span of the sample data, there are some problems in data processing such as different statistical sizes and missing data. In order to make the data reflect the actual situation better, we make up for the missing data values and make the data before and after better convergence , Which can reduce human errors in data and improve the accuracy of subsequent models.

1.3.3 Model establishment and solution.

(1) Grey relational analysis model

A. Model establishing.

In gray relational analysis, the closer the curve is, the greater the correlation between sequences will be.

Step1: We select the industrial output value of each state, GDP and population as the reference series, the energy profile as a comparative series. Among them, the reference number is marked as $x_w(k)$, compared to the number of $x_i(k)$.

Step2: Here, we also choose to deal with the range method, as follows:

$$x_{ij}^{'} = \frac{x_{ij} - m_j}{M_j - m_j}, (i = 1,2,\cdots,50,\ j = 1,2,3,4,) \tag{1}$$

Among them, $M_j = \max_{1\le i\le 50}\{x_{ij}\}$, $m_j = \min_{1\le i\le 50}\{x_{ij}\}, (j = 1,2,3,4)$, then the dimensionless measure of the indicator becomes $x_{ij}^{'} \in [0,1]$.

Step3: Calculate the correlation coefficient, the formula is

$$\eta_i(k) = \frac{\min_i \min_k |x_i(k) - x_w(k)| + \rho \max_i \max_k |x_i(k) - x_w(k)|}{|x_i(k) - x_w(k)| + \rho \max_i \max_k |x_i(k) - x_w(k)|} \tag{2}$$

And $|x_i(k) - x_w(k)|$ is the absolute error, $\min_i \min_k |x_i(k) - x_w(k)|$ is the minimum difference between the two levels; ρ is the resolution, the range of which is $\rho = 0.5$.

Step4: Calculate the degree of correlation, the formula is

$$r_i = \frac{1}{n}\sum_{k=1}^{n} \eta_i(k) \tag{3}$$

r_i Is the relevance of x_i.

B. Model solving.

According to the above formula, we calculate the correlation coefficient between each energy index and GDP, population and industry, as shown in Tab.2.

Tab 2. Correlation coefficient

	CLTXB	NGTXB	PMTCB	RETCB
GDP	0.7376	0.7722	0.7835	0.8273
POPULATION	0.7753	0.7278	0.7923	0.8013
INDUSTRY	0.7573	0.7816	0.8137	0.8034

We can see from the table that all the correlation coefficients are greater than 0.7 that is, the correlation between energy indicators and population, industry and GDP is very high. Among them, the correlation between RETCB and GDP is the highest, which is 0.8273. So we can speculate that there is a high correlation between renewable energy and GDP. We can also see that there is a relatively high correlation between renewable energy indicators and industry and GDP. In contrast, natural gas energy consumption and coal consumption indicators are weakly related to GDP, population and industry.

(2) Energy evolution simulation based on ruff neural network model

A. Model establishing.

We put $X = [x_1, x_2, \cdots, x_n]$ in the input layer, and the actual output is $Y = [y_1, y_2, \cdots, y_p]$. The output of the k of Neuronal network in the input layer is

$$\hat{y}_k = \sum_{i=1}^{m} w_{ik} R_i(X), k = 1,\cdots, p \tag{4}$$

And n is the number of input layer nodes; m is the number of hidden layer nodes; p is the number of output layer nodes; w_{ik} is the connection weight of the k of neuron in the hidden layer and the k of neuron in the output layer; $R_i(X)$ is the function of the k of neuron in the hidden layer that is

$$R_i(X) = \exp\left(-\|X - C_i\|^2 \Big/ 2\sigma^2\right), i = 1, 2, \cdots, m, \tag{5}$$

And X is the n-dimensional input vector; C_i is the center of the i of basis function and has the same dimension as X ; A is the width of the i of basis function; m is the number of sensing units. $\|X - C_i\|$ Is the norm of the vector? $R_i(X)$ Has a unique maximum at C_i . For a given input, there is only a small Part of the center near X is activated.

B. Model solving.

We use the population, GDP, and industrial output of each state from 1960 to 2009 as the input layer, and the coal consumption, natural gas consumption, petroleum consumption and renewable energy consumption as the output layer. In determining the number of neurons in the hidden layer of RBF, we find that the highest correct rate was 88.90% when the number of neurons was set to 4. Because energy consumption and population, economy and industry have a high degree of relevance, RBF can give a more reasonable forecast value and simulates a complete evolution path according to the changes of different values of population, economy and industry. Finally, we simulate and evolve the four energy profiles of CA, AZ, NM, and TX in different years and generate graphs.

Below, we will make a similarities and differences analysis of energy profiles of different states based on graphs.

However, before the analysis of the similarities and differences, we list us the demographic, economic, and industrial data of the states and compare them separately. As shown in Table.3.

Tab 3. Data range

	GDP		POP		IND	
	min	max	min	max	min	max
CA	67809	1983926	17668	36961	24232	396355
AZ	4482	262045	1521	6343	1604	58407
NM	3030	86318	989	2037	1134	22510
TX	29252	1243387	10159	24309	13390	456429

From the table, we can see that AZ and NM, CA and TX in the three data have a very big gap, but AZ and NM, CA and TX have a greater similarity between the internal. These figures will result in differences and similarities in energy consumption among the states. We will analyze this as follows.

1.3.4 Analysis on the impact of population, economy and industry on energy evolution

(1) Analysis of the similarities and differences of fossil fuels

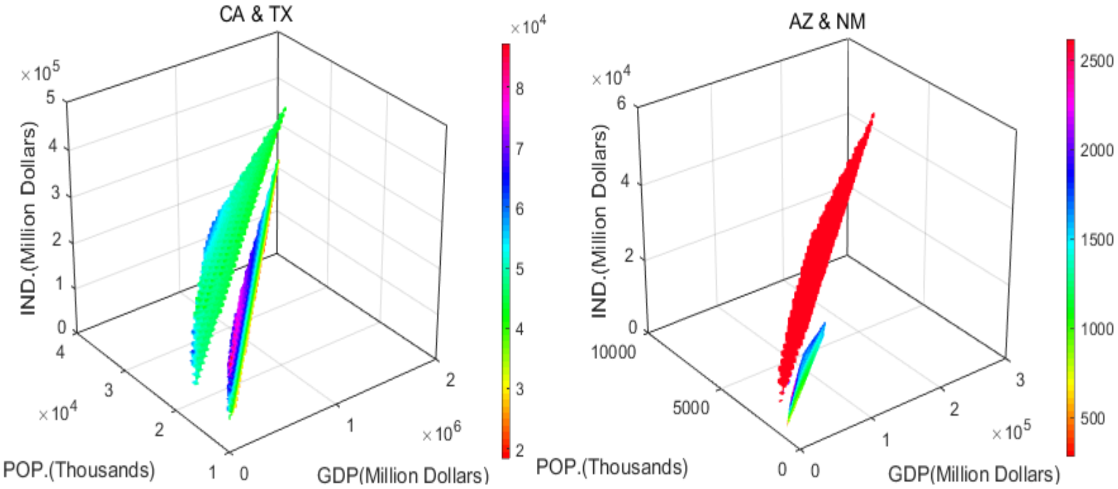

Fig 5. Comparison of CLTXB

In the first figure, we can see that in terms of coal consumption, the usage of California is higher than that of Texas, and the trend of the two figures is similar, and the color of the end of the figure is also getting closer with greater similarity. In the second picture, Arizona uses significantly more coal than New Mexico. At the same time, we can see that the trend of the graphs in both figures is gradually increasing, indicating that population, economy and industry have a great impact on energy use. The more developed the economy, the larger the population, the more developed industries and the greater the use of energy many. Comparing the two figures shows that although the colors of the graphs are the same, the first figure has a larger unit, indicating that energy use in California and Texas is significantly higher than those in Arizona and New Mexico. This further validates the conclusion that population, economy and industry have a greater impact on energy use.

Due to space limitations and the similar nature of oil, natural gas and coal, we will not go into detail here.

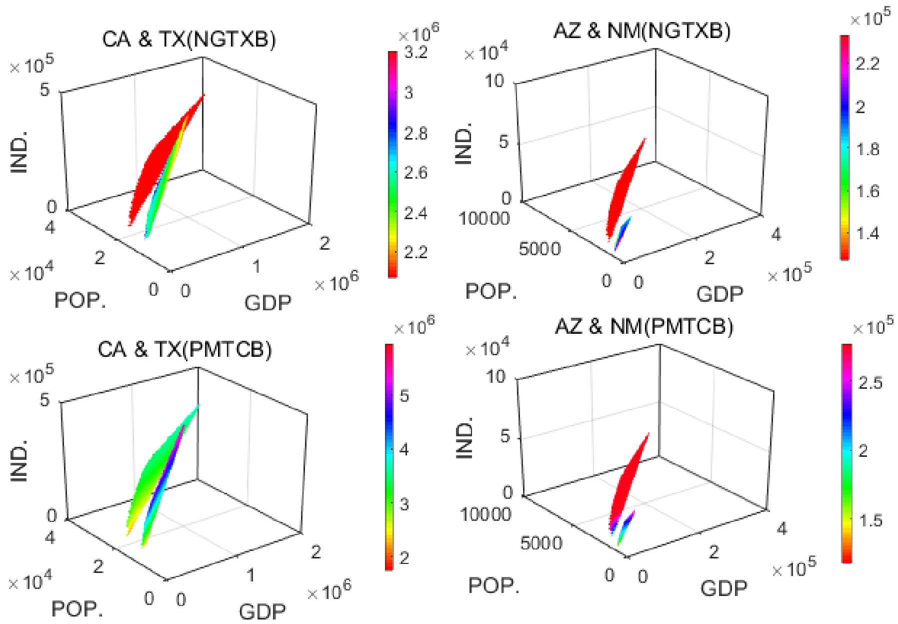

Fig 6. Comparison of NGTXB and PMTCB

(2) Similarities and differences on renewable energy analysis

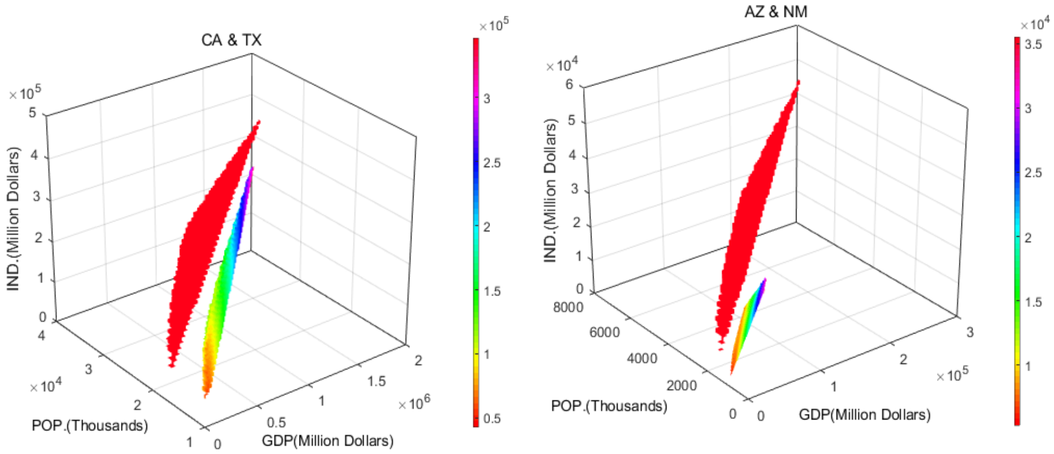

Fig 7. Comparison of RETCB

As the chart shows, California has more renewable energy than Texas, and Arizona has more clean energy than New Mexico. With the development of population, economy and industry, California and Arizona have gradually reduced the use of renewable energy, and the energy use of Texas and New Mexico is gradually increasing. This picture shows that although the population, economy and industry can have an impact on the use of renewable energy, the impact may not be large. And each region will have its own uniqueness, and the uniqueness of the region will have an impact on the use of clean energy. We will analyze the regional uniqueness of the states below.

In order to better address the use of renewable energy in the states, we propose that governors be able to strengthen cooperation between states, based on data analysis. Due to the late development of renewable energy, the technology has not been perfected. And four states are close, and energy is similar. Close cooperation among states will help save costs, improve renewable energy applications and better develop renewable energy.

1.3.5 Geography, climate impact analysis

Geographical conditions and climate status in all regions are relatively stable and will not change significantly with other external forces. These basically stable factors will form the regional uniqueness of each state. Which is reflected in all aspects of the state and the economic development Level, residents living habits, energy efficiency and so on. As the impact of geography and climate can not be quantified, and perennial basically stable, quantified little significance, we will analyze the impact of geography and climate on energy use from the side.

We substitute fixed economic, demographic and industrial values (308590, 12176, and 85251) into the neural network models of each state, and the resulting differences in energy use among the states are the effects of geography and climate on energy use.

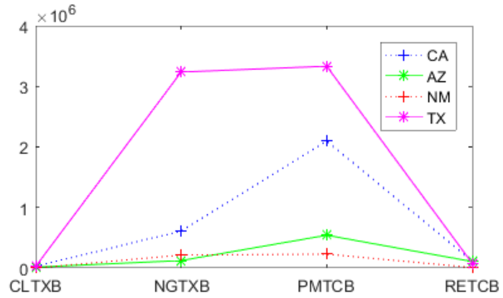

Fig 8. Comparison of CA, AZ, NM and TX

In the economy, population and industrial fixed value circumstances, the consumption is Texas> California> Arizona> New Mexico.

This shows that the regional uniqueness caused by geography and climate can greatly affect the energy use of each state, and this influence will gradually deepen with the development of time. However, this effect is not significant in the use of renewable energy because renewable energy has only started to develop in recent years. Moreover, without being affected by the long-term impact of the geographical and climatic conditions of a region, the effects of geography and climate are not significant.

2. ACTION SUGGESTION

From the policy performance table, we can see that four states can reach cooperation in renewable energy, petroleum and total energy. However, California and Texas need to curb their use of natural gas. Therefore, we can adopt the following policies.

Market policy:

In the area of renewable energy, all states can work together to open up the market and actively invest in and construct the renewable energy market to promote the industrialization of renewable energy.

Price policy:

Increase the price of natural gas and reduce the demand for natural gas

Trade policy:

Reduce the import of natural gas and curb the supply of natural gas.

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