Energy Consumption and Economic Development Based on GEP Model in Hebei Province

Huifang Cheng*
Library
Hebei University of Engineering
Handan 056038, China
*Corresponding author

Jianli Zhao
Hebei Electric Power Design & Research Institute
Shijiazhuang, 050031, China

Haihua Qing
Handan Institute of Water Resources and Hydropower Research
Handan 056038, China

Abstract—**This paper explorers the causal relationship between energy consumption and economic growth using data of Hebei Province. The study covers the period of 1980 to 2011.We have applied gene expression programming to analyses how they evolved together. Two ways adopted in the forecast, the one is based on the total energy consumption, and the other is based on energy intensity per GDP. Respectively, we build the GEP models for evolution. Two groups of predicted value and the actual value of the data fitting is good. It is found that the model can fit the variation trend of energy consumption and energy intensity per GDP by simulation. The model can reflect the actual status of the energy consumption and economic relations, which can provide scientific basis for policy makers to make a decision. The impact of economic growth and energy consumption is found to be positive.**

Keywords-energy consumption; gene express programing; evolution and analysis

I. INTRODUCTION

Energy and environment have been the common concerned problem for humankind. It is also an important problem during social and economic development so it is significant to study about the relationship between energy consumption and economic growth. Energy consumption and economic growth is influenced by various factors in long span of the study period. Therefore, modeling energy consumption with good accuracy has become even more complex in such a complex environment. So a model can self-learning, without assumes parameters is more naturally than affixed parameter one used by the existing energy economics literature (for example, see [1] Y Zhang [2] Ozturk, 2010; [3] Payne, 2010;), and which play a vital role in understanding the dynamic relationship between energy consumption and economic growth, formulating reasonable strategies and policies for energy and environment and avoid costly mistakes. And because of this energy consumption models are developed specific to the area of Hebei Province.

In recent years, evolutionary algorithms have been used in various energy researches because of their ability to self-learn and solve complicated problems [4-7]. As a promising variant of genetic programming, gene expression programming (GEP) is a kind of general adaptive random search algorithm, without any prior knowledge, do not understand things internal mechanism, only under the condition of the experimental data develop more accurate formula [8].Therefore it has very good mapping ability to manage complicated nonlinear problems with more input and uncertainty. And researchers have made use of this advantage in predicting [8-9], data mining [10-11]and have made very good progress. Therefore, based on gene expression programming algorithm to energy consumption evolution model is established.

The rest of the paper is organized as follows: Section 2 gives energy consumption status and data sources of study area, Section 3 presents GEP model and simulation, Section 4 reports the empirical analysis of results and finally, Section 5 concludes the study.

II. ENERGY CONSUMPTIONCURRENT SITUATION AND DATA SOURCES

In recent years, China has a wide range, long haze pollution weather affects hundreds of millions of people, and Beijing-Tianjin-Hebei has become "heavy disaster area”. Energy market in Hebei province has a rapidly developing due to heavy industrial structure, rapid urbanization and enormous population. However, energy sources in Hebei are quite scarce. In present situation, authorities are necessary to accurately reproduce the relationship between economic growth and energy consumption by using an accurate model.

The data used in this study are taken from the Hebei Statistical Yearbook, and cover 1998−2011. The variables used are total energy consumption (measured in 10000 tons of SCE), and Gross domestic product (measured in one hundred million yuan) in Hebei province. The specific district selected for the study and the timeframe was dictated by data availability.

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III. Gene expression programming evolution model and the simulation experiment for Energy consumption and economic development

In addition to the traditional way of training the relationship between total energy consumption and economic growth, we applied gene expression programming algorithm to our system. Gene Expression Programming (GEP), first introduced by (Ferreira 2001) [13], is an evolutionary algorithm that evolves computer programs and predicts mathematical models from experimental data. GEP begins with a random population of candidate solutions in the form of chromosomes. The chromosomes are evaluated based on a fitness function and selected by fitness to reproduce with modification via genetic operations. The new generation of solutions goes through the same process until the stop condition is satisfied. The fittest individual serves as the final solution [14].

A. Buildselection Environment

On the basis of the research GEP schema theory[16], our GEP model consists of a well-balanced set in order to avoid the creation of models that can only solve a partial, and often marginal, aspect of the overall problem. Function sets are chosen and shown in table 2.Parameters for the energy consumption problem is shown in table 3; Max. Fitness: 1000. During the experiments sampling data of 12 -30cases were used for training, the rest cases for testing.

B. The Choice of Fitness Function

The success of a problem not only depends on the way the fitness function is designed but also on the quality of the selection environment [14].

Then the square of multiple correlation coefficients is used as the fitness to evaluate all the individuals and is expressed by equation (1).

R2=1-SSE/SST (1)

$$SSE = \sum_{j=1}^{m} \left(y_j - \hat{y}_j \right)^2 ,$$

$$SST = \sum_{j=1}^{m} \left(y_j - \bar{y}_j \right)^2 ,$$

In Eq. (1), every individual's forecast is denoted by $\hat{y}_j$ and the mean value of the generation by $\bar{y}_j$ .As it stands, R2 cannot be used directly to measure the fitness of the evolved models, the following equation is used to evaluate the fitness of an individual with efficiency:

Fitness=R2*1000(2)

C. The Simulation of Energy Consumption and Economic Evolution Model

In the training stage, two set of training data (1998-2010 data set of Total Energy consumption and energy intensity per GDP) are provided, then they are ranked and evolved with their scores by GEP using GeneXproTools. In the testing stage, another two data set (1980-2011 data set of Total Energy consumption and energy intensity per GDP) are supplied to test the similarity between the twice evolutionary processes.

The simulation results are shown in Fig. 1-Fig. 4, where it becomes obvious that the GEP algorithm fits these values well. In addition, the validation indexes RMSE, MSE, RAE, MAE,RSE, RRSE and R2 were compared with a part of experimental data and the estimated values also show that the greater the amount of given data, the model is more powerful. The proposed modelfortheperiod1980–2011have the best fitness (924, 943) than the propose model fortheperiod1998–2010 (836,788).

IV. Conclusion

GEP model has attractive features, such as the ability toself-learning.GEP model is developed by getting the relationship between energy consumption and economic development, such as energy intensity per GDP. When a robust GEP model with high fitting and reliability was constructed, statistical data of different period used in the training stage are shown to be accurately estimated. The experiment results show that the proposed method is feasible and available. Compared with the whole economic development speed and level in Hebei province, the energy consumption growth rate maintained a positive relationship. Payne Industrial proportion is larger in the economy in Hebei province. Therefore, Hebei is in urgent need of development of green energy, developing low-carbon economy, the sustainable development of the scientific road. Actually it is so.

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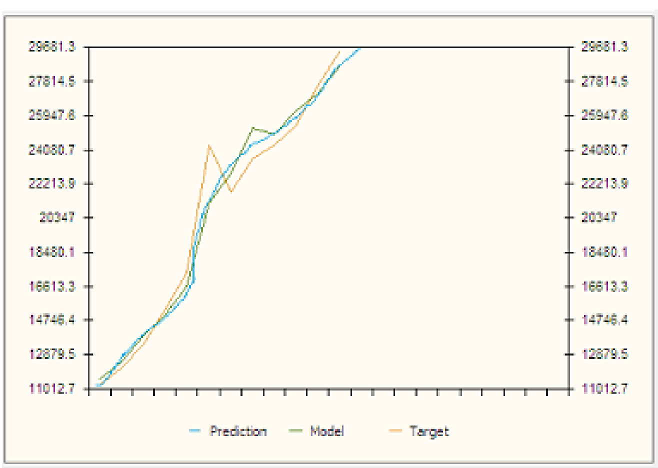

FIGURE 1. THE EVOLUTION CURVE OFTOTAL ENERGY CONSUMPTION WITH GENETIC ALGORITHM 1998-2010

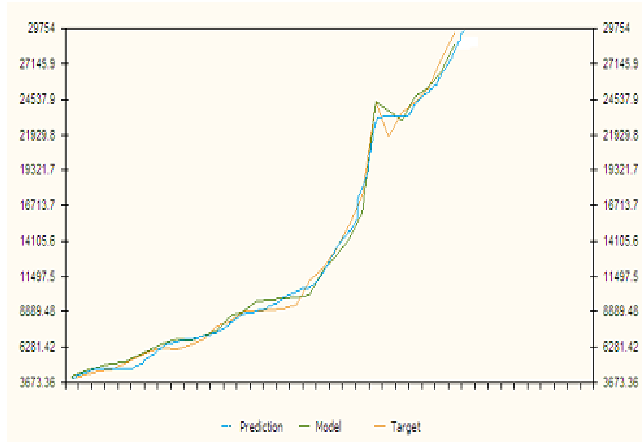

FIGURE 2. THE EVOLUTION CURVE OFTOTAL ENERGY CONSUMPTION WITH GENETIC ALGORITHM 1980-2011

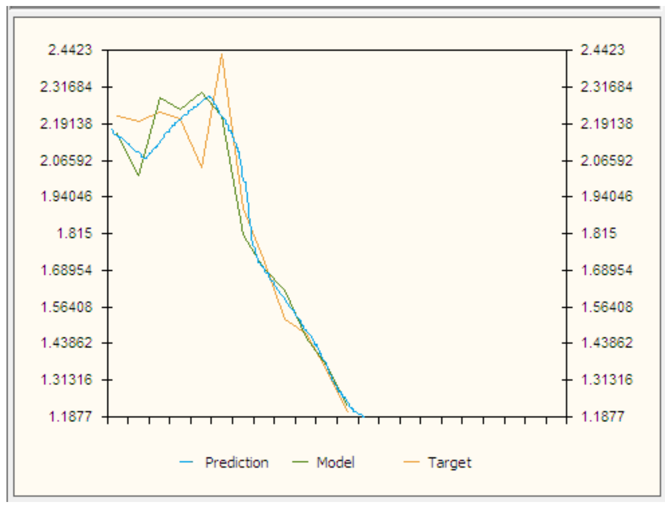

FIGURE 3. THE EVOLUTION CURVE OFENERGY INTENSITY PER GDP WITH GENETIC ALGORITHM 1998-2010

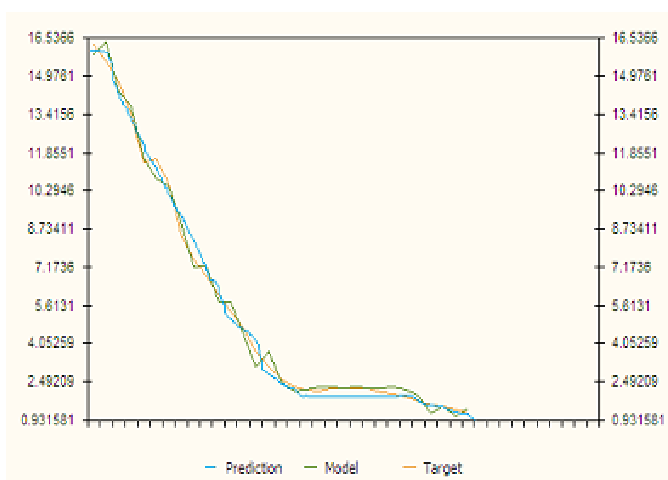

FIGURE 4. THE EVOLUTION CURVE OFENERGY INTENSITY PER GDP WITH GENETIC ALGORITHM 1980-2011

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TABLE I. PRIMARY CONSUMPTION IN HEBEI PROVINCE FROM 1998-2011

Time	Total Energy consumption (10000 tons of SCE)	energy intensity per GDP	Time	Total Energy consumption(10000 tons of SCE)	energy intensity per GDP
1980	3120.50	14.23	1996	8938.47	2.59
1981	3627.80	16.30	1997	9033.01	2.28
1982	3929.05	15.6256	1998	9151.12	2.15
1983	4185.78	14.78	1999	9379.27	2.08
1984	4475.00	13.47	2000	11195.71	2.22
1985	4548.85	11.465	2001	12114.29	2.20
1986	5079.52	11.63	2002	13404.53	2.23
1987	5516.81	10.57	2003	15297.89	2.21
1988	5962.40	8.50	2004	17347.79	2.04
1989	6169.26	7.50	2005	24321.87	2.43
1990	6124.22	6.83	2006	21794.09	1.90
1991	6471.93	6.037	2007	23585.13	1.73
1992	6866.29	5.37	2008	24321.87	1.52
1993	7861.92	4.65	2009	25418.79	1.47
1994	8168.62	3.73	2010	27531.11	1.35
1995	8892.41	3.12	2011	29498.29	1.20

TABLE II. FUNCTION SET FOR THE ENERGY CONSUMPTION PROBLEM

Representation	Definition	Representation	Definition	Representation	Definition	Representation	Definition
+	x+y	x3	x^3	sin	Sin(x)	sqrt	$x^{1/2}$
-	x-y	Exp	e^x	Tan	Tan(x)	x2	x^2
*	x*y	log	logx	Cos	Cos(x)	Not	(1-x)
/	x/y	Abs	|x|				

TABLE III. PARAMETERS FOR THE ENERGY CONSUMPTION PROBLEM

parameter	value	parameter	value	parameter	value
Number ofgenerations	10000	Population size	30	IS transposition	0.1
Number of fitness cases	30(Table 1)	Function set	(Table 2)	RIS transposition	0.1
Terminal set	(-10,10)	Head length	7	Fitness function	Eq(1)
Number of genes	4	Linking function	+	Gene recombination	0.1
Mutation	0.044	Gene transposition	0.1	One-point recombination	0.3
Inversion	0.1	Precision	0.0001	two-point recombination	0.3

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