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ENERGY SAVINGS EFFECT MEASUREMENT OF ENERGY POLICIES FROM 1999 TO 2004 IN JIANGSU PROVINCE

Abstract: *An improved GM(1,1) model is presented to measure energy savings effect of energy policies from 1999 to 2004 in Jiangsu province. The improved GM(1,1) can take full advantage of new information in sequence of raw data for a small sample size prediction. The predicted energy intensities are derived from the prediction of applying the improved GM(1,1) model. And the energy savings are obtained from the differences of predicted energy consumption and actual energy consumption from 1999 to 2004. From the results we can find that in the beginning of implemented energy policies the energy consumption grows slowly and energy savings effects are obvious. However, the actual energy consumption has exceeded the predicted energy consumption in terms of results in this paper in 2004. This phenomenon represents that the energy policies has reached the best effects and some new energy savings policies should be formulated to keep both economic growth and energy savings sustainable. Our analysis in this paper is consistent with the decision-making of Chinese government. In the end of 2004 the "medium and long term specific schema on energy savings" is formulated and some other energy savings measures have been formulated to achieve the goal in the specific schema from 2004.*

Keyword: *energy savings; energy intensity; GM(1, 1) model; energy policy; effect measurement*;

JEL Classification: C53, C63

1. Introduction

Energy is one of essential factors for prompting economic development. However, with the development of economics the demands of energy consumption increase greatly. Energy consumption rises from 571.4 million tons of coal equivalent in 1978 to 2850 million tons of coal equivalent in 2008. Energy consumption per capita rises from 0.59 ton of coal equivalent in 1978 to 2.15 tons of coal equivalent in 2008. Although China is rich in some energy resources, the size of China's population means that the resources per capita are lower than the world average level. As some energy resources can not satisfy demands in China, there are a large number of energy resources imported from other countries in recent years. Especially in 2000, there exist 233.1 million tons of coal equivalent lacking in China. From this group of simple data we can find that contradiction of energy providing and demanding in China is serious all the time.

China government has adopted a series of administrative and technological measures to reduce energy consumption and raise energy utilization efficiency while prompting economic development for many years. Here we simply introduce some government policies formulated and implemented to save energy consumption from 1980. In 1980, Chinese government formulated "the sixth five-year plan to energy savings", which emphasizes heavily on energy savings in a basis of energy exploiting and savings. "Energy savings management temporary regulation" was promulgated in 1986. There are also other measures or regulations formulated and implemented in the 1980s. These measures' implementation improves energy consumption and energy savings in a certain level. Since the 1990s, China government further strengthens management of energy consumption and energy savings. A series of regulations and laws about energy savings problems are formulated and implemented such as "outlines of technological policy of energy saving" in the early 1990s and "the law of energy conservation" in 1998 etc. These regulations and laws put emphasis not only on energy savings but also environment conservation. Since the 21st century, China government continues to emphasize on the energy savings, environment conservation and social sustainable development. "Energy savings middle term and long term special plan" was formulated and implemented in 2004. In this plan the goal of energy savings in 2010 is emphasized on and the goal of energy savings in 2020 is presented. The goal of energy intensity of per 10000 RMB is 2.25 and 1.54 tons of coal equivalent in 2010 and 2020 respectively. These goals decrease from 2.65 tons of coal equivalent in 2002 (GDP are calculated at a constant price of 1990 in the specific plan). To achieve the new goal of energy savings some novel regulations and laws will be formulated and implemented in the future. The mainly comprehensive energy savings policies are shown in Table 1.

Table 1. Mainly comprehensive energy savings policies

Year	Energy policy
1980	The sixth five-year plan to energy savings
1986	Energy saving management temporary regulation
1990	The eighth Five-year plan of energy savings
1994	Several suggestions to reinforcement of saving and utilization of nature resources
1995	The ninth Five-year plan of energy savings
1996	Regulation of supervision of energy savings of the ministry of coal industry
1998	Law of energy conservation
1999	Regulation of energy savings utilization of key energy using units
2001	Regulation of electricity savings
2004	Medium and long term specific plan on energy savings
2005	Notification to implementation of design standards of energy savings of new built civil construction
2005	Guidance of promotion of energy and land savings civil construction and public building
2005	Regulation of energy savings utilization of civil construction
2006	Notification to preventing blind re-expansion of high energy-consuming industries
2006	Decision to reinforcing energy savings issue
2007	Suggestions to energy savings and emission reduction of coal industry
2007	Advice of comprehensive operation scheme on energy savings and reduce of pollutants emission
2007	Emergent notification to reinforcement of industrial structure adjustment and preventing blind re-expansion of high energy consumption industries
2008	Modified law of energy conservation

2. Literature review

Energy savings represent energy which is not used (Boonekamp, 2006). Then it is difficult for us to measure them directly. However, to measure energy savings effects of energy policies or some activities a question such as what will energy consumption have been if energy policies or some activities have not been implemented in a period of time? The general idea for measurement of energy savings effects is shown as figure 1. And the key factor is determination of reference energy consumption. There are a number of methods presented to develop the determination of reference energy consumption under the assumption of without corresponding policies or activities implemented. Fisher-Vanden et al. (Fisher-Vanden et al., 2002) identifies the factors driving the fall in total energy use and energy intensity and sources of variation in energy intensity in China. In addition, from the impact of R&D spending on energy intensity some suggestions such that firms are using resources for energy saving innovations are given. Boonekamp (Boonekamp, 2004) makes a presentation and analysis of historical energy use and emission trends by a MONIT tool which is based on constructing energy balances. The actual energy use changes are unraveled into fourteen factors, from which the MONIT system offers policy makers an integrated set of monitoring results. Fang (Fang, Tian and Sun et al., 2012; Fang, Tian, Fu, 2013) presents a novel three-dimensional and four-dimensional energy saving model and emission-reduction chaotic system, respectively. Boonekamp and Gijsen et al. (Boonekamp & Gijsen et al., 2004) present the realized energy savings in the Netherlands for the period of 1995-2002. They pay more attention to the uncertainty margins that result from the uncertainty in the input data and the quality of the variable utilized to calculate the reference energy use. Bowie and Malvik (Bowie & Malvik, 2005) propose energy savings targets to be achieved by improved energy end-use efficiency. The purpose of authors is to look at what they are measuring in the way of energy efficiency improvements, to present common structures and concepts for some energy savings measuring methodologies. Alsema and Nieuwlaar (Alsema & Nieuwlaar, 2001) present an overview of energy efficiency measures for all sectors of the Dutch economy from 1995-2020. The way saving potentials is calculated in the report. They use the frozen technology to regard changes at the level of energy systems and saving options. In this method they derive total reference energy consumption in a chosen year by means of replacing every actual efficiency value with the base year value (Boonekamp, 2006). Eyre (Eyre, 2013) presents a general application of the feed in tariffs (FITs) on the demand side and sets out the economic arguments in the context of changing energy market. A bottom-up method to calculate realized energy savings in conjunction with other factors is proposed in an application of evaluating the household sector in the Netherlands (Boonekamp, 1997). Reference energy consumption is calculated by setting the mix of more or less efficiency systems and appliances equal to that in the base year. Wang et al. (Wang, Wang and Zhao, 2008) investigates the interactions among major barriers preventing the practice of energy savings in China. An interpretive structure modeling is used to summarize barriers hindering the practice of energy savings and explain interrelations among them.

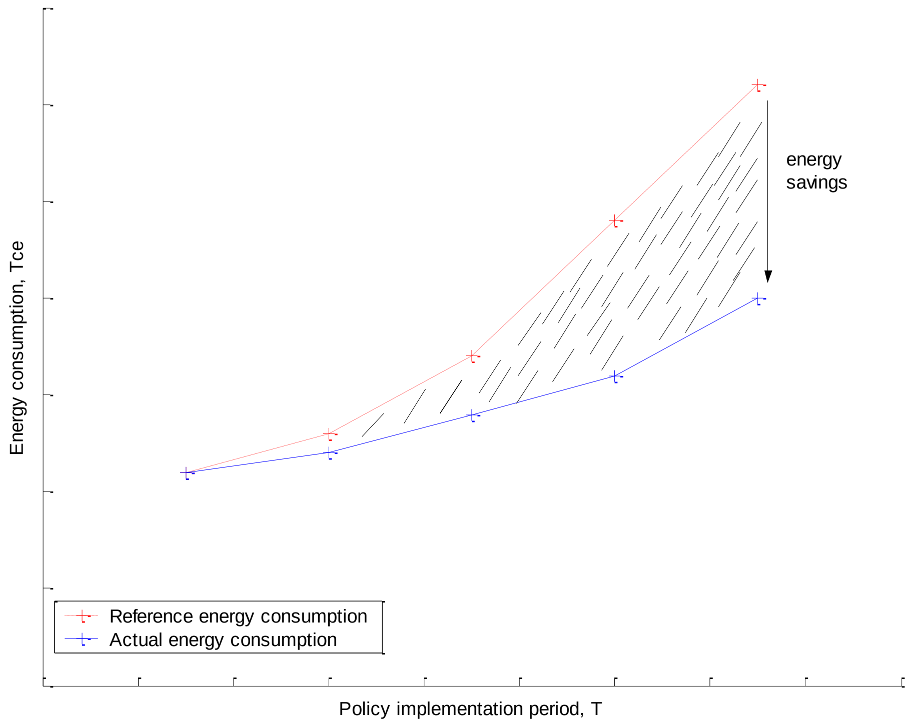

Figure 1. Energy savings from reference energy consumption and actual energy consumption

In this paper we will investigate energy savings effect measurement of energy policies group from 1999 to 2004 in Jiangsu province in China. “The law of energy conservation” which is implemented from the beginning of 1998 is the representation of the energy policies group. During the period between 1998 and 2004 there are not other more important comprehensive energy savings policies than that formulated and implemented in China. Then we believe that the energy savings in Jiangsu province is attributed mainly to the law of energy conservation during this stage. An improved GM(1,1) model is presented to predict energy intensity under the assumption of non corresponding energy policies implemented and then the reference energy consumption data can be calculated. And the differences between the predicted reference energy consumption data and the actual energy consumption data are the energy savings of the energy policy.

The remaining of this paper is organized as following. Section 3 is used to illustrate the energy savings measurement method. The original GM(1,1) model is introduced briefly and the improved GM(1,1) model is presented in this section. An empirical analysis of energy savings measurement of energy policy utilizing the method presented in this paper in section 4. Conclusions are given in section 5

3. Energy savings effect measurement method based on an improved GM(1,1) model

Grey systems theory was presented by professor Deng initially in 1982 (Deng, 1982). From then on the novel theory has been applied in a wide range of fields. Grey systems theory focuses mainly on uncertain systems with partial information known and partial information unknown. Grey systems theory can describe laws of system operations correctly and monitor them effectively and extract valuable information from generations and developments of partially known information (Liu & Lin, 2006). GM(1,1) model is one of important grey models in grey systems theory. Constructing models with small sample size is an essential characteristic for GM(1,1) model.

3.1 Original GM(1,1) Model

Suppose that

$$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \cdots, x^{(0)}(n))$$

is a non-negative sequence of raw data and

$$X^{(1)} = (x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n))$$

is the sequence derived from first-order accumulative generation operator (1-AGO) working on $X^{(0)}$, where,

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i)\,, \quad k = 1,2,\cdots,n$$

Then the grey derivative of $X^{(1)}$ is

$$d(x) = x^{(0)}(k)$$

Proof is omitted (Liu & Lin, 2006).

For the sequence $X^{(1)}$ derived from first-order accumulative generation operator working on $X^{(0)}$, the sequence

$$Z^{(1)} = (z^{(1)}(2), \cdots, z^{(1)}(n))$$

is a sequence of generated mean value of consecutive neighbors, where

$$z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1), \quad k = 2,3,\cdots,n$$

Definition 1(Liu & Lin, 2006): the equation

$$x^{(0)}(k) + az^{(1)}(k) = b$$

is a grey differential equation, also called GM(1,1) model. The abbreviation GM(1,1) represents the grey model of first order and one variable.

For the GM(1,1) model, $\hat{a} = [a, b]^T$ is a sequence of parameters, where parameters a and b are called the development coefficient and grey action quantity, respectively, and let

$$Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix}, \quad B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix}$$

Then the least square estimate sequence of the GM(1,1) model

$$x^{(0)}(k) + az^{(1)}(k) = b$$

satisfies $\hat{a} = (B^T B)^{-1} B^T Y$.

Proof is omitted (Liu & Lin, 2006).

From the least square estimators, we can derive the expression of parameter estimates as following

$$\begin{cases} a = \dfrac{\sum_{k=2}^{n} x^{(0)}(k) \cdot \sum_{k=2}^{n} z^{(1)}(k) - (n-1) \cdot \sum_{k=2}^{n} x^{(0)}(k) \cdot z^{(1)}(k)}{(n-1)\sum_{k=2}^{n} [z^{(1)}(k)]^2 - [\sum_{k=2}^{n} z^{(1)}(k)]^2} \\ b = \dfrac{1}{(n-1)} \cdot [\sum_{k=2}^{n} x^{(0)}(k) + a \cdot \sum_{k=2}^{n} z^{(1)}(k)] \end{cases}$$

Definition 2 (Liu & Lin, 2006): Suppose that $X^{(0)}$ is a non-negative sequence, $X^{(1)}$ is the sequence of 1-AGO from $X^{(0)}$, and $Z^{(1)}$ is the sequence of generated mean value of consecutive neighbors, parameters $\hat{a} = [a, b]^T$ is derived in terms of the least square estimate, then

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b$$

is called a whitened equation of GM(1,1) model.

The time response function of the whitened function mentioned above is given by

$$x^{(1)}(t) = (x^{(1)}(1) - \frac{b}{a})e^{-a(t-1)} + \frac{b}{a}$$

The time response function of GM(1,1) model is given by

$\hat{x}^{(1)}(k+1) = (x^{(1)}(1) - \frac{b}{a})e^{-ak} + \frac{b}{a}$, $k = 1, 2, \cdots, n$, as $x^{(1)}(1) = x^{(0)}(1)$, then the time response function of GM(1,1) model can be derived as following,

$$\hat{x}^{(1)}(k+1) = (x^{(0)}(1) - \frac{b}{a})e^{-ak} + \frac{b}{a}.$$

As the time response function of GM(1,1) model is results of sequence derived from 1-AGO, then we need to restore values of the time response function of GM(1,1) model then we can obtain the prediction values of raw data. The restored values of raw data can be given by

$$\hat{x}^{(0)}(k+1) = \alpha^{(1)}\hat{x}^{(1)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) = (1 - e^{a})(x^{(0)}(1) - \frac{b}{a})e^{-ak},$$

$k = 1, 2, \cdots, n$, and $\alpha^{(1)}$ represents first-order inverse accumulative generation operator (IAGO). We can predict raw data points using the above expression.

3.2 An Improved GM(1,1) Model

From preceding introduction we know that the time response function of grey differential equation can be rewritten as following,

$$x^{(1)}(t) = ce^{-at} + \frac{b}{a},$$

where c is a constant. This constant is related to the initial condition in the time response function. In the original GM(1,1) model the initial condition is set equal to $x^{(1)}(1)$. As GM(1,1) model is constructed from small sample sizes, then new information application is critical for this model. And the principle of new information priority is put highly emphasis on about the construction of grey models in grey systems theory. However, the initial condition $x^{(1)}(1)$ in the original time response function can not make full use of new information. Dang et al. (Dang, Liu and Chen, 2004) presents an improved initial condition which is set the initial condition equal to $x^{(1)}(n)$. This improvement can make full use of new information. However, sometimes the restored values overestimate the raw data especially when the absolute of development coefficient is much smaller in the time response function. Here we set the initial condition equal to $0.5(x^{(1)}(1) + x^{(1)}(n))$, which not only can make full use of new information but also incorporate the originally initial condition into the newly initial condition of time response function. This expression of the initial condition can be more suitable for the small sample size prediction when we are not sure about the fluctuation trends of predicted data.

As

$$x^{(1)}(t) = ce^{-at} + \frac{b}{a},$$

Then if we let $t = 1$, then the following equation can be derived,

$$x^{(1)}(1) = ce^{-a} + \frac{b}{a};$$

And if we let $t = n$, then the following equation can be obtained,

$$x^{(1)}(n) = ce^{-an} + \frac{b}{a};$$

From these two equations mentioned above, if we set the initial condition equal to

$0.5(x^{(1)}(1)+x^{(1)}(n))$, then we can obtain the constant *c* as following,

$$c = 2(1+e^{a(n-1)})^{-1}(\frac{x^{(1)}(1)+x^{(1)}(n)}{2}-\frac{b}{a})e^{an} .$$

Then the restored values can be given by,

$$\hat{x}^{(0)}(k) = 2(1-e^{a})(1+e^{a(n-1)})^{-1}(\frac{x^{(0)}(1)+x^{(1)}(n)}{2}-\frac{b}{a})e^{-a(k-n)} .$$

4. An Empirical Study In Jiangsu Province In China

Jiangsu province is located along the east coast of China. Jiangsu's economy develops rapidly in recent years. In 2008 Jiangsu's nominal GDP exceeds 3 trillion RMB, which makes it the third largest GDP of all provinces except for Guangdong province and Shandong province and an annual growth rate of 12.5%. Rapid growth of economy in Jiangsu province accomplishes with the more energy consumption definitely. Then the energy savings effects of energy policy in Jiangsu province can reflect the total energy savings effects in China in some sense. It will be helpful for check and evaluation of energy policy implementation and further formulation of energy policy in the future.

4.1 Data Collection in Energy Savings Measurement of Energy Policy

In this paper we utilize actual energy intensity data (1993-1998) in Jiangsu province before "the law of energy conservation" implementation (in the beginning of 1998) to predict the energy intensity values from 1999-2004 respectively applying the improved GM(1,1) model.

Table 2. Actual energy intensity in Jiangsu province from 1993 to 2005

Year	GDP (10^8 RMB)	Energy consumption (10^4 tce)	Energy intensity (tce per 10^4 RMB)
1993	4368.50	3334.25	0.7632
1994	5088.49	3507.30	0.6893
1995	5870.22	8047.00	1.3708
1996	6586.38	8111.00	1.2315
1997	7376.75	7991.00	1.0833
1998	8188.19	8118.00	0.9914
1999	9015.20	8164.00	0.9056
2000	9970.81	8612.00	0.8637
2001	10982.98	8881.00	0.8086
2002	12264.07	9609.00	0.7835

2003	13934.80	11060.00	0.7937
2004	15990.24	13651.00	0.8537
2005	18305.66	16841.21	0.9200

Note: GDP and index are from statistical year of Jiangsu 2006. GDP are calculated in terms of a constant price of 2005; Energy consumption data are from China energy statistic yearbook 2006.

4.2 Predict Energy Intensity After Implementing 'Law Of Energy Conversation' in Jiangsu Province

In terms of the improved GM(1,1) model mentioned in section 3 and the actual energy intensity data from 1993 to 1998 in table 2, the sequence of actual energy intensity data

$$X^{(0)} = (0.7632, 0.6893, 1.3708, 1.2315, 1.0833, 0.9914),$$

we can derive the parametric estimators as following, $a = -0.0256, b = 0.9866$

$$\hat{x}^{(0)}(k) = 2(1-e^{a})(1+e^{a(n-1)})^{-1}\left(\frac{x^{(0)}(1)+x^{(1)}(n)}{2} - \frac{b}{a}\right)e^{-a(k-n)}$$

$$= 1.129e^{0.0256(k-6)}, \quad k = 2,3,\cdots,12,$$

where k represents corresponding year, e.g. $k = 2$ represents 1994.

When $k = 7$, we can obtain the predicted energy intensity value in 1999 is 1.1583. To improve prediction precision of energy intensity, we take the metabolic techniques in grey systems theory, namely that we add the newly predicted value in the sequence of raw data and at the same time we delete the first value in the sequence of raw data. Then we can attain a new sequence of raw data to predict the energy intensity in 2000.

$$X^{(0)} = (0.6893, 1.3708, 1.2315, 1.0833, 0.9914, 1.1583)$$

$$a = 0.0630, b = 1.3925$$

$$\hat{x}^{(0)}(k) = 2(1-e^{a})(1+e^{a(n-1)})^{-1}\left(\frac{x^{(0)}(1)+x^{(1)}(n)}{2} - \frac{b}{a}\right)e^{-a(k-n)}$$

$$= 1.0149e^{-0.063(k-5)}, \quad k = 2,3,\cdots,12$$

When $k = 7$, we can obtain the predicted energy intensity value in 2000 is 0.9529.

Adopt the same procedure, we can obtain the predicted energy intensity values as shown in table 3.

Table 3. Predicted energy intensity from 1999 to 2005

Year	1999	2000	2001	2002	2003	2004	2005
Energy intensity (tce per 10^4 RMB)	1.1583	0.9529	0.9442	0.9365	0.9043	0.8260	0.8293

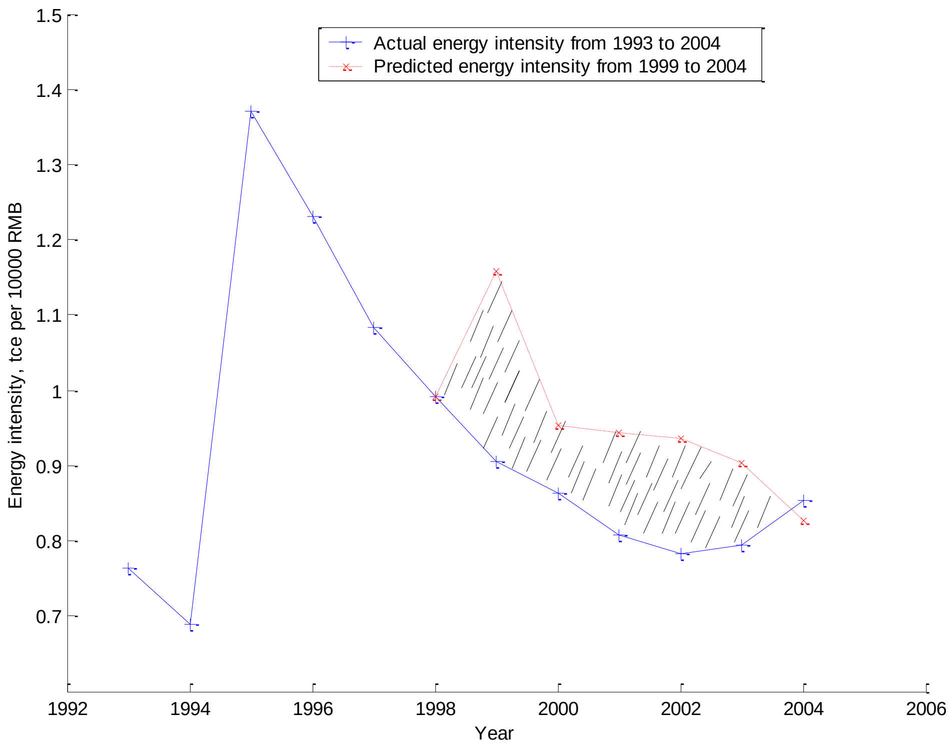

Figure 2. Comparison of actual energy intensity and predicted energy intensity from 1999 to 2004

Figure 2 shows that the actual energy intensity increases in the beginning and the energy intensity arrives at maximum value 1.3708 tce per 10000 RMB in 1995. To prompt sustainable economy growth and also energy savings, Chinese government considers formulating further measures to guarantee energy savings. The law of energy conservation is implemented from the beginning in 1998. Considering delays of policy implementation then we measure energy savings effect of energy policy from 1999. The shadow between the curve of actual energy intensity and predicted energy intensity is the difference of energy intensity which represents the effect of implemented energy policy. And from the difference of energy intensity the energy savings at corresponding years are shown as table 4. It is worth being noted that the actual energy intensity increases from 2002 and exceeds the predicted energy intensity at 2004 which represents that the marginal effect of implemented energy policy is decreasing gradually and with the rapidly economic growth some new energy policies need to be formulated in the future.

Table 4. Energy savings from implementing energy policy

	Actual energy intensity	Predicted energy intensity	Difference of Energy intensity	Year energy savings
1999	0.9056	1.1583	0.2527	2278.1410
2000	0.8637	0.9529	0.0892	889.3963
2001	0.8086	0.9442	0.1356	1489.2921
2002	0.7835	0.9365	0.153	1876.4027
2003	0.7937	0.9043	0.1106	1541.1889
2004	0.8537	0.8260	——	——

As the actual energy intensity exceeds the predicted energy intensity at 2004, then we say that no energy savings are produced from the implemented energy policy in 2004. The total energy savings from 1999 to 2004 are 80.74 million tons of coal equivalent.

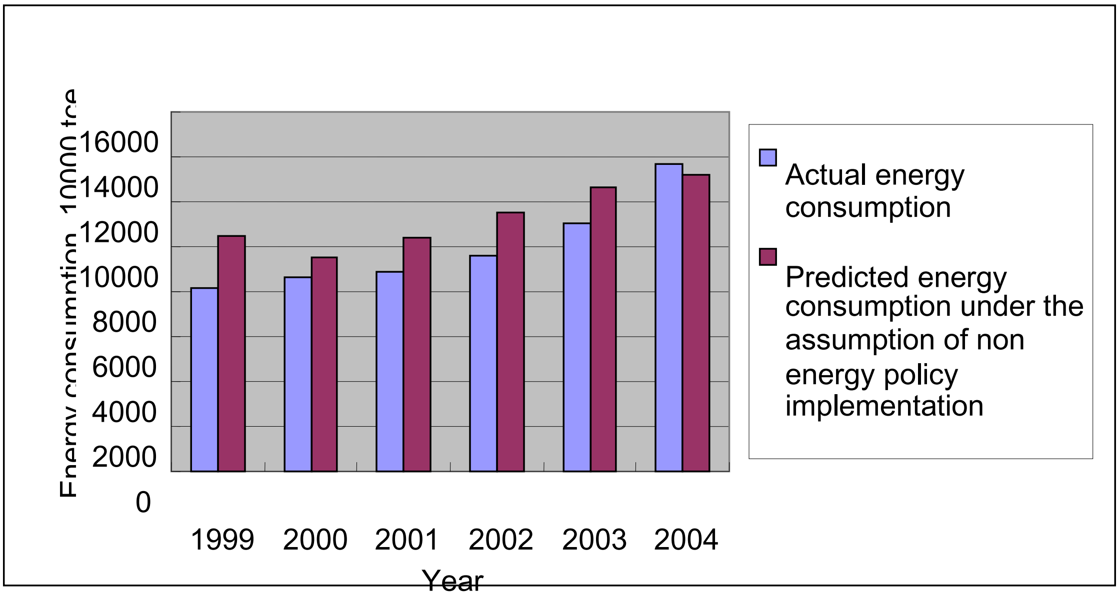

Figure 3. Trend of the actual energy consumption and the predicted reference energy consumption under the assumption of non-energy policy implementation

Figure 3 shows the trend of actual energy consumption and predicted reference energy consumption under the assumption of non corresponding energy policy implemented from 1999 to 2004 in Jiangsu province. The actual energy consumption grows slowly in the beginning of the law of energy conservation formulated. However, the actual energy consumption exceeds the predicted reference energy consumption in 2004. This expresses that some new energy savings policies need to be formulated to keep both economic growth and energy savings sustainable. Chinese government makes rapidly decisions in the light of the sudden changing of energy consumption. “Medium and long term specific plan on energy savings” has been formulated in the end of 2004. This is in consistent with our analysis in this paper. There are some other plans of energy savings formulated from 2004 to achieve the goal set in the “medium and long term specific schema on energy savings”.

5. Conclusions

An improved GM(1,1) model is presented to measure the energy savings effect of energy policies from 1999 to 2004 in Jiangsu province. The improved GM(1,1) model can take full advantage of new information in the sequence of raw data. For a small sample size prediction the improved can derive better prediction results. The predicted energy intensity is obtained under the assumption of non new energy policies implemented. Then the predicted reference energy consumption can be calculated in terms of the energy intensity formula. And the energy savings can be derived from the difference of the predicted reference energy consumption and the actual energy consumption in the corresponding year respectively.

From the calculation results we can see that in the beginning of energy policy implemented the actual energy consumption grows slowly and energy savings effect is obvious. However, the actual energy consumption has exceeded the predicted reference energy consumption in 2004 which represents that the effect of being implemented energy policies has reached the best and some new energy savings policies should be formulated to keep both economic growth and energy savings sustainable together. Our analysis in this paper is consistent with corresponding energy policies decision-making of Chinese government. The “medium and long term specific plan on energy savings” has been formulated in the end of 2004 to further strengthen the energy savings in China. To achieve the goal of energy savings in the “medium and long term specific plan on energy savings” some other energy consumption measures have also formulated from 2004.

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