The Intervention Model of Total Final Energy Consumption in China

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Abstract. In the present paper, we establish an intervention model in the time series analysis method according to the total final energy consumption of China collected from 1965 to 2018, and then we make a prediction of future total final energy consumption of China. Based on the prediction we can put forward some suggestions to the planning and development for the total final energy consumption of China.

1. Introduction
The total final energy consumption is the sum consumption of all kinds of energy in national economy industry and households in certain period and region [1]. Over the years, energy has always been a focus problem in development of China economy. Solution of energy issue is the key of sustainable development of China economy. With the aggravating of the energy demand and contest in worldwide, countries are considering the relationship between economic development and energy reserves, energy efficiency, energy demand forecasting, environmental conditions, limiting factor and others based on respective national conditions, they are taking appropriate policies and activity in order to alleviate the energy issue [2]. The forecast of energy consumption is an important part in energy planning; a good forecast could meet the requirements of economic development, it is significance not only for the development of China energy industry, but also for economy, political and social stability and building a harmonious environment [3]. The chief of National Energy Bureau Zhang Baoguo said that China will take the significant reduction of energy consumption and carbon dioxide emission as a binding target. Therefore, we build a model with statistical methods to forecast of China total energy consumption as a basis for more accurate predictions, a reasonable theoretical basis for the National Development and Reform Commission to develop energy planning and policy recommendations.

2. Data Analysis
We analyzed 54 data of total final energy consumption of china collected from 1965 to 2018 from China Statistical Yearbook, and considered it a sample of time serial marked as \( \{X_t\} \). Using SAS 9.4M5, we get timing plot Figure 1.

Intuitive seen from Figure 1, 1965-2018 China total energy consumption has a significant linear upward trend is clearly non-stationary time series, in order to eliminate the linear trend of the impact of \( \{X_t\} \), we differential \( \{X_t\} \) and get the sequence denoted by \( \{\nabla X_t\} \), differential \( \{\nabla X_t\} \) and get the sequence denoted by \( \{\nabla^2 X_t\} \) timing plot shown in Figure 2.
Known from Figure 2, \( \{P^2X_t\} \) is nearly stable. By studying the autocorrelation function and partial autocorrelation function of \( \{P^2X_t\} \) to judge the stability shown in Figure 2.

### Table 1. White Noise Test to \( \{P^2X_t\} \)

| To Lag | Chi-Square | DF | Pr > ChiSq | Autocorrelations |
|--------|------------|----|------------|------------------|
| 6      | 11.50      | 6  | 0.0740     | -0.118           |
| 12     | 17.67      | 12 | 0.1262     | 0.234            |
| 18     | 21.35      | 18 | 0.2623     | -0.122           |
| 24     | 23.31      | 24 | 0.5016     | 0.044            |

#### Model

**3.1. ARIMA Model and Test**

1. Time series difference: In this study the second difference of \( \{X_t\} \). Here, we define that \( X'_t = P^2X_t \), where \( \nabla \) denotes the difference operator.

2. White noise test: The white noise tests for \( \{X'_t\} \) is shown in Table 1. It is found that each \( p\)-value is more than 0.05, which mean \( \{X'_t\} \) is white noise series.

3. The ARIMA model:

#### Table 2. Minimum Information Criterion

| Lags | MA 0      | MA 1      | MA 2      | MA 3      | MA 4      | MA 5      |
|------|-----------|-----------|-----------|-----------|-----------|-----------|
| AR 0 | 16.83566  | 16.89092  | 16.96147  | 16.98479  | 17.04592  | 16.96794  |
| AR 1 | 16.8915   | 16.96722  | 17.03564  | 17.06182  | 17.12293  | 17.045    |
| AR 2 | 16.9505   | 17.02759  | 17.10199  | 17.13843  | 17.19818  | 17.04333  |
| AR 3 | 16.98982  | 17.06522  | 17.1423   | 17.21531  | 17.27521  | 17.09366  |
| AR 4 | 17.04726  | 17.11966  | 17.196    | 17.26621  | 17.33538  | 17.15964  |
| AR 5 | 16.91608  | 16.97539  | 17.00092  | 17.07442  | 17.12318  | 17.2       |

In Table 2, we find Minimum Table Value is BIC \((0,0) = 16.8356\), so, we get the ARIMA \((0,2,0)\) model by BIC:

\[
(1 - B)^2X_t = \varepsilon_t \tag{1}
\]

where \( \varepsilon_t \) is a white noise series.
By using Model (1), we get the following 5 prediction of the total energy consumption in future shown in Table 3.

| Year   | Forecast       | Std Error       | 95% Confidence Limits |
|--------|----------------|-----------------|------------------------|
| 2018   | 461239.0000    | 4629.8316       | 452164.6968 470313.3032 |
| 2019   | 473949.0000    | 10352.618       | 453658.2412 494239.7588 |
| 2020   | 486659.0000    | 17323.244       | 452706.0664 520611.9336 |
| 2021   | 499369.0000    | 25358.632       | 449666.9944 549071.0056 |
| 2022   | 512079.0000    | 34335.750       | 444782.1662 579375.8338 |

Table 3 shows the forecast of 2018 close to its true value of 4.612 billion tons of standard coal, through careful observation of Figure 1, we do not consider 3 outliers: 1997, 2001, 2003. We try to improve ARIMA (0,2,0) and see if can get a more accurate model by consider the 3 outliers [4].

### 3.2. Intervention Model and Test

Figure 1 shows that China total energy consumption began to decline in 1997 which is caused by the impact of the 1997 Asian financial crisis, weaken domestic demand resulting the reduction of demand for energy products, gradually formed Asian financial crisis make a short-term impact of China energy consumption, we selected the following intervention models by considering Figure 3:

\[ Y_t^{(1)} = \frac{c^{(1)}}{1-\delta_{1}^{(1)} L} P_t^a \]  

Where,

\[ P_t^a = \begin{cases} 1, & a = 1997 \\ 0, & a \neq 1997 \end{cases} \]

China total energy consumption began to increase slowly in 2001 which is caused by following events: China successfully joined the World Trade Organization (WTO); Beijing won the bid to host the 2008 Olympics Games; “911” in United States. The three events stimulated the growth of China total energy consumption. This is a continuous growth process (2002-2008, Figure.1), this effect is gradually over time; we selected the following intervention model by considering Figure 3:

\[ Y_t^{(2)} = \frac{c^{(2)}}{1-\delta_{1}^{(2)} L} B^2 S_t^b \]  

Where,

\[ S_t^b = \begin{cases} 0, & b < 2001 \\ 1, & b \geq 2001 \end{cases} \]

After 2003, the growth rate of China total energy consumption is far more than 1965-1996, because the second plenary meeting of the CPPCC National Committee meeting in 2003, China has proposed must be from a macro, long-term point of view to study and control energy issues, the development of energy strategy comply with our national conditions. Subsequently under the influence of national policy to expand domestic oil exploration, while also promoting overseas energy industry, so that the total energy consumption in China increased significantly. Immediate effect caused by the intervention of national policy, China's total energy consumption growth, thus the impact of the interventions selected the following model:

\[ Y_t^{(3)} = C^{(3)} S_t^c \]
Where, 
\[ S_c^\varepsilon = \begin{cases} 0, & c < 2003 \\ 1, & c \geq 2003 \end{cases}. \]

By using conditional least squares estimation with SAS 9.4M5 program we estimate the parameter of model (5), the parameter \( C^{(1)} \) is not significant. So, we try to get rid of the intervention factor \( P_{t_0} \) and then estimate the parameter, we get model (5):

\[
X_t = \frac{8414.1}{1 - 1.29168B + 0.92075B^2} S_c^\varepsilon + \frac{1}{1 - 1.29168B + 0.92075B^2} \varepsilon_t \tag{5}
\]

Known from Table 4 the parameters of the model all passed test, Table 5 shows model (5) residual series test, it is found that each \( p\)-value is more than 0.05, which means that \( \{\varepsilon_t\} \) is white noise series, so model (5) is the final intervention model [5].

### Table 4. Intervention Model Parameter Estimate

| Parameter | Estimate | Standard Error | t Value | Approx Pr > | Lag | Variable | Shift |
|-----------|----------|----------------|---------|-------------|-----|----------|-------|
| SCALE1    | 8414.1   | 2663.5         | 3.16    | 0.0030      | 0   | s1       | 2     |
| DEN1,1    | 1.29168  | 0.07001        | 18.45   | <.0001      | 1   | s1       | 2     |
| DEN1,2    | -0.92075 | 0.08979        | -10.25  | <.0001      | 2   | s1       | 2     |

### Table 5. Intervention Model Residual Error Test

| To Lag | Chi-Square | DF | Pr > ChiSq | Autocorrelations |
|--------|------------|----|------------|------------------|
| 6      | 11.22      | 6  | 0.0818     | -0.103 -0.048 0.125 0.245 -0.318 -0.170 |
| 12     | 15.03      | 12 | 0.2399     | 0.028 -0.042 -0.228 -0.035 0.075 0.062 |
| 18     | 18.59      | 18 | 0.4173     | -0.131 0.022 0.043 0.092 -0.101 0.108 |
| 24     | 21.66      | 24 | 0.5995     | 0.056 -0.002 -0.122 0.118 -0.021 -0.044 |

### 4. Forecast Results

Forecast the 2018-2022 total energy consumption in China by using intervention model (5), shown in Table 6.
Table 6. Forecast of 2018-2020 Total Energy Consumption in China (intervention model)

| Year | Forecast   | Std Error   | 95% Confidence Limits |
|------|------------|-------------|-----------------------|
| 2018 | 465933.9547 | 3990.7173   | 458112.2925 473755.6170 |
| 2019 | 485027.2374 | 8923.5152   | 467537.4690 502517.0059 |
| 2020 | 501978.4199 | 14931.897   | 472712.4397 531244.4002 |
| 2021 | 514608.1677 | 21858.059   | 471767.1593 557449.1761 |
| 2022 | 523628.3454 | 29595.952   | 465621.3458 581635.3450 |

Know from Table 6, the forecast value 4.6594 billion tons of standard coal in 2018, China's total energy consumption is very close to the actual value of 4.6400 billion, Table 3 and Table 6 can be seen that the intervention model (5) 95% predicted interval length shorter than the ARIMA model (1), means intervention model (5) not only points to more accurately forecast, and predict higher accuracy, can also be intuitive from Table 6 that the intervention model (5) fitting results would be better. The above shows that if the time series need to considered unexpected factors, the intervention model provides a more accurate method.

5. Conclusions
(1) Asia financial crisis in 1997 makes China total energy consumption declined but slightly, 2 years of duration (1997-1998), we consider it is a random disturbance of the total consumption of China but not sudden event;
(2) In the second half of 2001, the three major events lagging behind for 6 years continued to affect China's energy consumption growth.
(3) The 2003 policy had an immediate effect on the growth of China energy consumption, which makes China total energy consumption from the 2003 annual increase of 80,121,040 tons of standard coal;
(4) The combination effect of 2 interventions makes a rapid growth of China total energy consumption from 2003: the growth rate in 2002 is less than 6%, 2003 is more than 15% while 16% plus in 2004. government departments did not take timely and effective response measures led to the 2005 China total energy consumption of up to 2.24682 billion tons of standard coal, to become the world's second-consuming country, leading to the future of energy-saving emission reduction task is arduous;
(5) In November 2014, the General Office of the State Council issued the Strategic Action Plan for Energy Development (2014-2020), which officially proposed the medium-term energy consumption to 2020, and the total primary energy consumption was controlled at About 4.8 billion tons of standard coal [6], as can be seen from Table 7, the annual growth rate of China's energy consumption in 2019-2022 will decrease year by year, but from the forecast value of Table 6, we can see that the total energy consumption in 2020 has exceeded 5 billion tons. Standard coal, judging from the current situation, China's energy conservation tasks are still very arduous, and relevant measures must be taken in time to conduct reasonable and effective interventions to ensure the implementation of China's green development goals during the 13th Five-year Plan.

Table 7. 2018-2022 forecast of China total energy consumption growth rate

| Year | Growth rate |
|------|-------------|
| 2018 | 0.4168%     |
| 2019 | 4.0979%     |
| 2020 | 3.4949%     |
| 2021 | 2.5160%     |
| 2022 | 1.7528%     |
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