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# The Opioid Crisis

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**Keywords:** Neutral network algorithm, principle component analysis, Cluster analysis, mix-effect linear model.

**Abstract:** The United States is in the midst of an opioid drug epidemic, which the Center for Disease Control has classified as a top public health concern, calling it the worst drug epidemic in US history. To address this problem, we analysed all US Census socia-economic data as well as the NFLIS data by using neutral network algorithm. And then, we use two ways of clustering to find the most possible locations to produce and output the opioid drug. In addition to it, we proposed several efficient strategy to solve this problem. After testing, our programs have heterogeneous effects on heroin crime incidents depending on counties pre-policy levels of prescriptions opioids per capital, with an 49-89% decrease in heroin crime within more opioid-dense conties.

## 1. Introduction

The United States is experiencing a national crisis regarding the use of synthetic and non-synthetic opioids, either for the treatment and management of pain (legal, prescription use) or for recreational purposes (illegal, non-prescription use). Federal organizations such as the Centers for Disease Control (CDC) are struggling to "save lives and prevent negative health effects of this epidemic, such as opioid use disorder, hepatitis, and HIV infections, and neonatal abstinence syndrome."1 Simply enforcing existing laws is a complex challenge for the Federal Bureau of Investigation (FBI), and the U.S. Drug Enforcement Administration (DEA), among others.

There are implications for important sectors of the U.S. economy as well. For example, if the opioid crisis spreads to all cross-sections of the U.S. population (including the college-educated and those with advanced degrees), businesses requiring precision labor skills, high technology component assembly, and sensitive trust or security relationships with clients and customers might have difficulty filling these positions. Further, if the percentage of people with opioid addiction increases within the elderly, health care costs and assisted living facility staffing will also be affected.

## 2. Problem Analysis

We have to use the NFLIS data provided, build a mathematical model to describe the spread and characteristics of the reported synthetic opioid and heroin incidents (cases) in and between the five states and their counties over time. Morever, we should use our model, identify any possible locations where specific opioid use might have started in each of the five states.

In order to deal with the following problems:

Are there any specific concerns the U.S. government should have?

Are what drug identification threshold levels do these occur?

Where and when does your model predict they will occur in the future?

### 2.1 Analysis of Specific Issues

Based on the data, the total number of drugs per year for each state in 2010-2017 and the total number of morphine colosine per year were calculated, resulting in the total number of synthetic opioids and heroin per year.

Taking the year as the abscissa and the total number of drugs as the ordinate, draw a scatter plot

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of the total number of drugs and the year of each state, as shown in figure 1.

Observe the trend of KY scatter plots, do one, two, and three polynomial fittings respectively and find the correlation coefficient. The correlation coefficient of cubic polynomial fitting is 0.8899 is greater than 0.8, indicating a good correlation. Similarly, the fitting polynomials of the other four states are obtained.

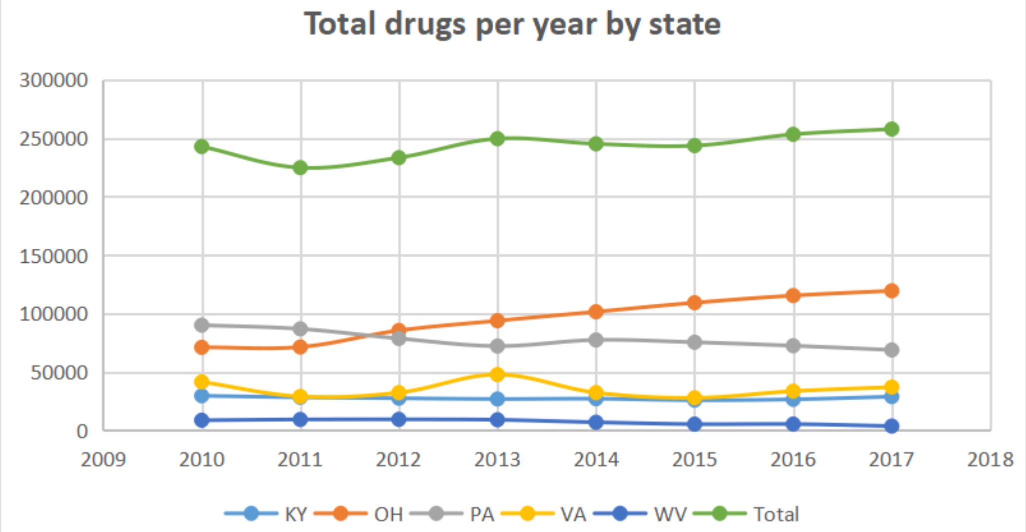


Figure 1 Total drugs per year by state

According to the data, we draw the states (KY, OH, PA,VA,WV) with the year as the abscissa and the total number of drugs as the ordinate. The trend of the total drug number and the year's polyline trend, and plot the total drug number at the top, as shown in figure 2.

We can see that the total number of drugs in each state changes with the trend of the year is very subtle: OH generally shows an upward trend, PA generally shows a downward trend, KY, WV, VA three states generally have a constant trend, but the cumulative total number of drugs with the year Growth is still on the rise.

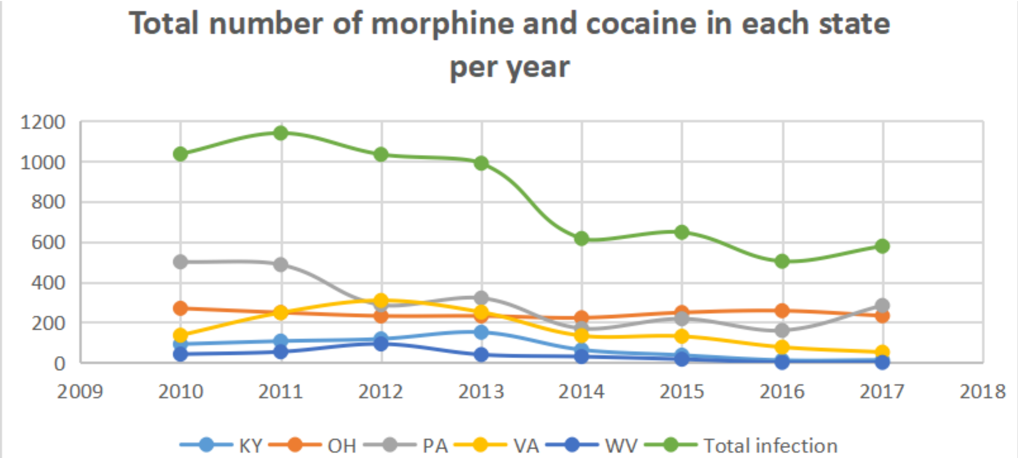


Figure 2 Total number of morphine and cocaine in each state per year

According to the data given, we draw the states (KY,OH,PA,VA,WV)with the year as the abscissa and the total number of the morphine and cocaine as the ordinate.The trend of the total drug number and the year's polyline trend, and plot the total infection at the top,as shown in figure 3.

The overall data is showing a downward trend. From the figure, we can see that the number of synthetic opioids and heroin per week has increased steadily with the growth of the year. Among them, OH state has a steady growth trend, and PA has a gradual decline trend, but PA, VA, The WV remains basically unchanged.

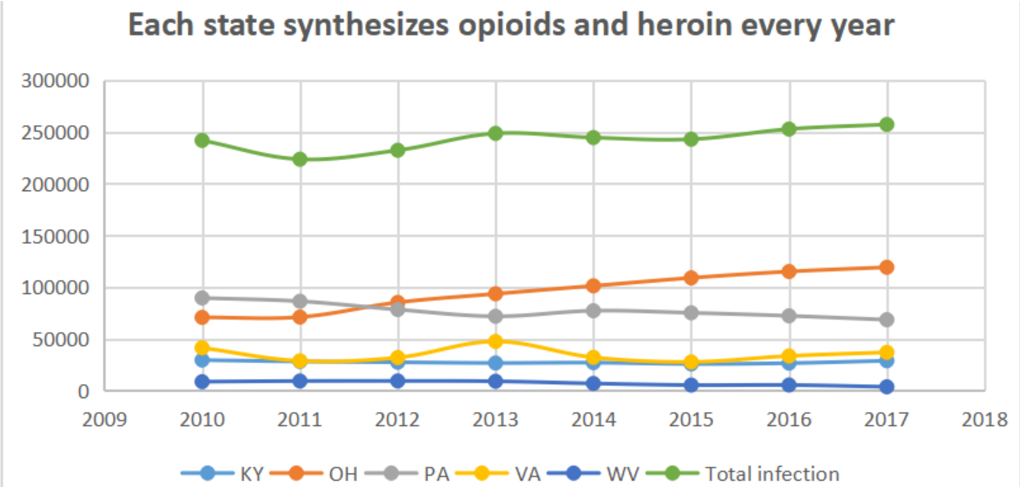


Figure 3 each state synthesizes opioids and heroin every year

## 3. Problem analysis and data processing

### 3.1 Problem Analysis

Using the data provided by NFLIS, a mathematical model was created to describe the spread (variation) and characteristics of the synthetic opioids and heroin events (cases) in the report over time between the five states and their counties.

### 3.2 Data elimination and completion

The above table data is programmed (or plotted for curve analysis) to analyze the data, and the data with larger offset is eliminated, and the mean of the adjacent years is used for completion processing, as shown in figure 4.

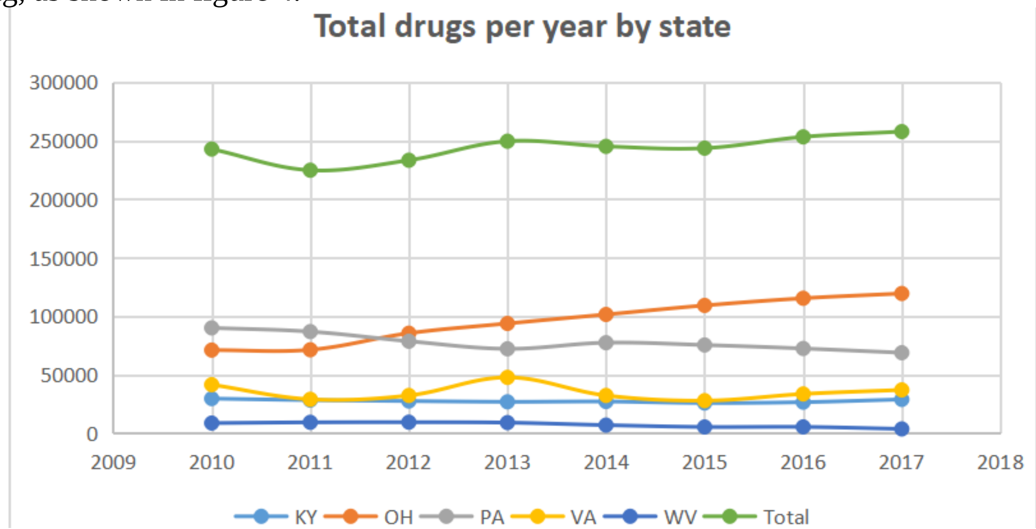


Figure 4 Total drugs per year by state

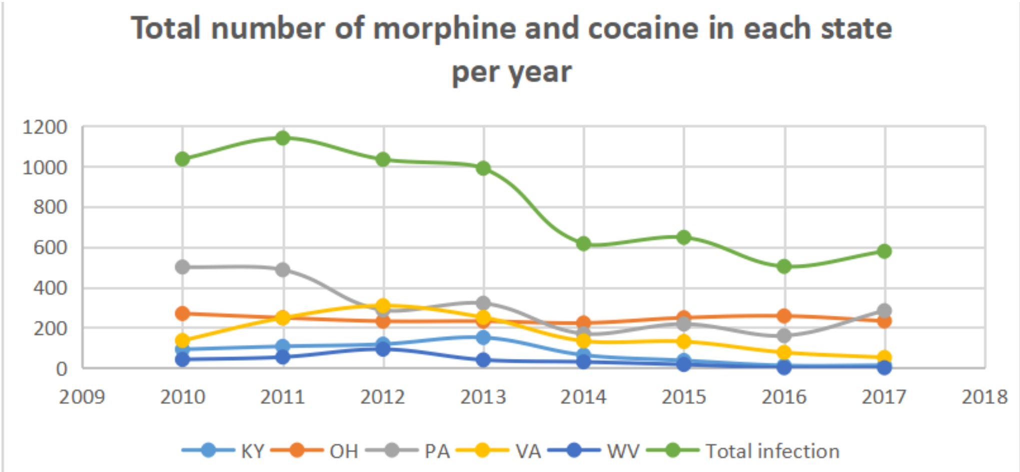

Figure 5 Total number of morphine and cocaine in each state per year

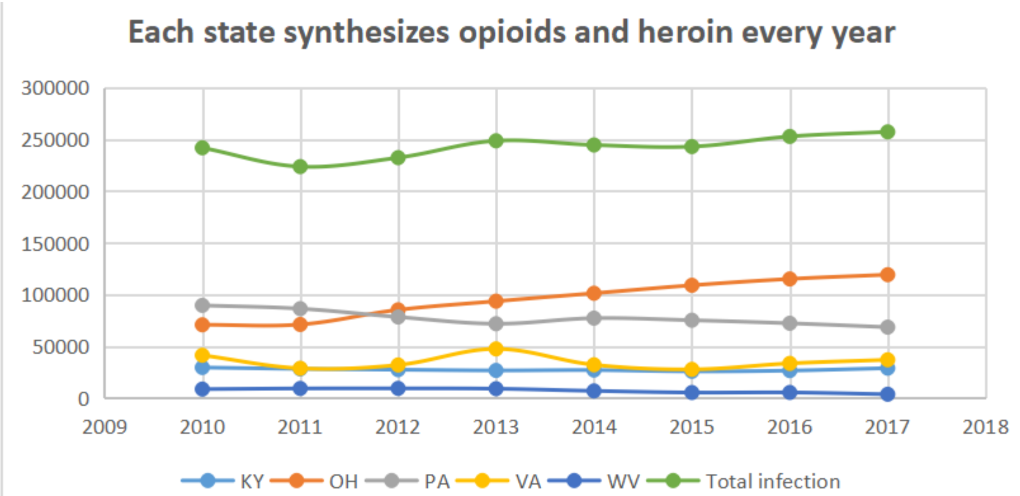

Figure 6 Each state synthesizes opioids and heroin every year

## 4. Model Establishment

### 4.1 Build a numerical fitting model

In order to derive the characteristic relationship of the drug with the year and predict the number of reports for the next three years, we need to use the fitting method to quantitatively solve the problem (Simiarly, the total amount of drug reports in the VA state is taken as an example).

First, plot the fit between the annual consumption of VA and time (year) as follows:

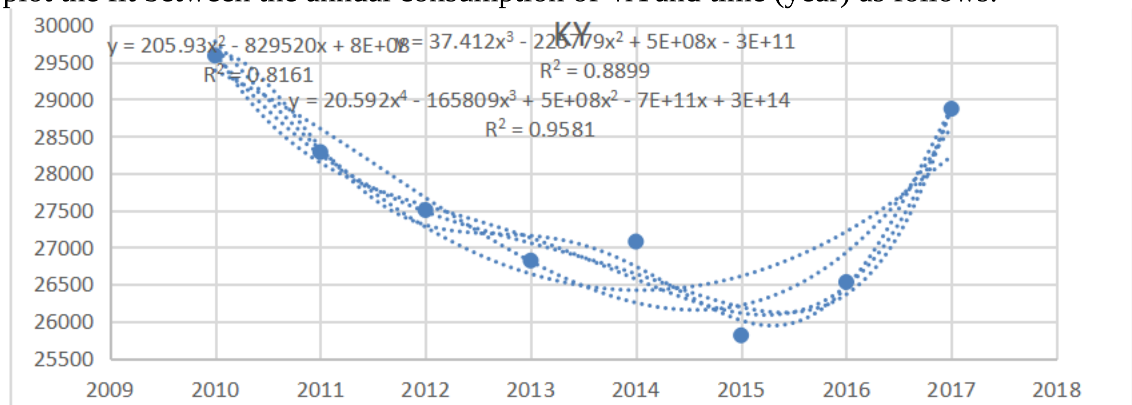

Figure 7 the fit between the annual consumption of VA and time (year)

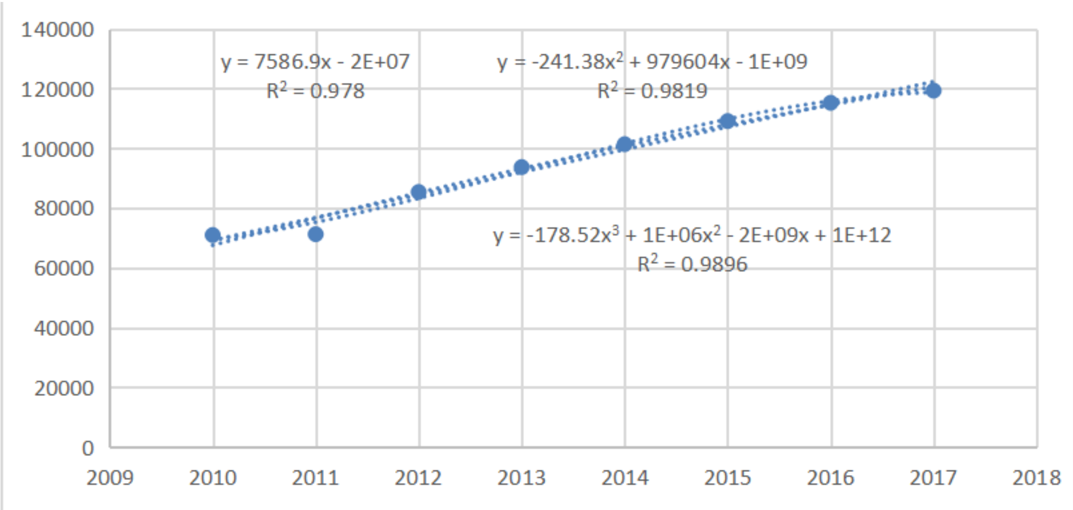


Figure 8 the fit between the annual consumption of OH and time (year)

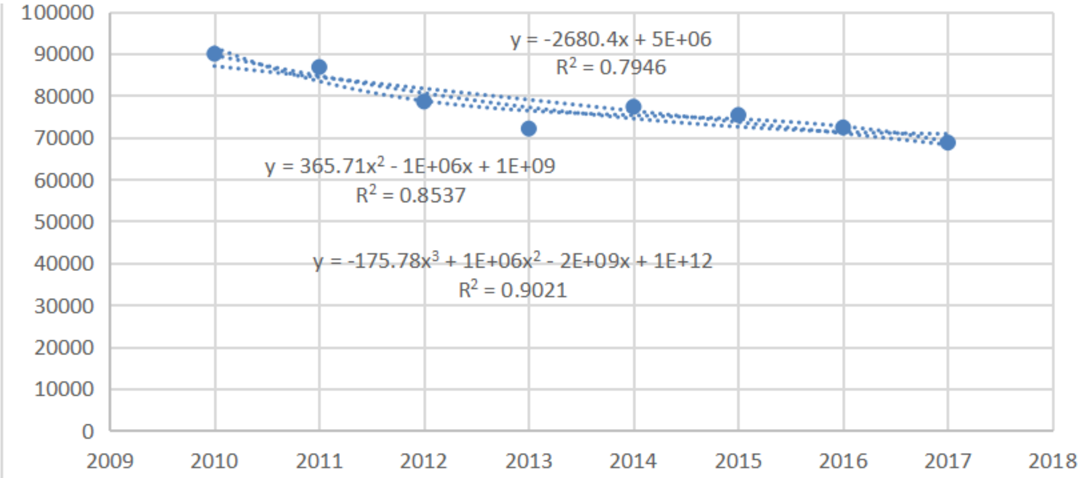


Figure 9 the fit between the annual consumption of PA and time (year)

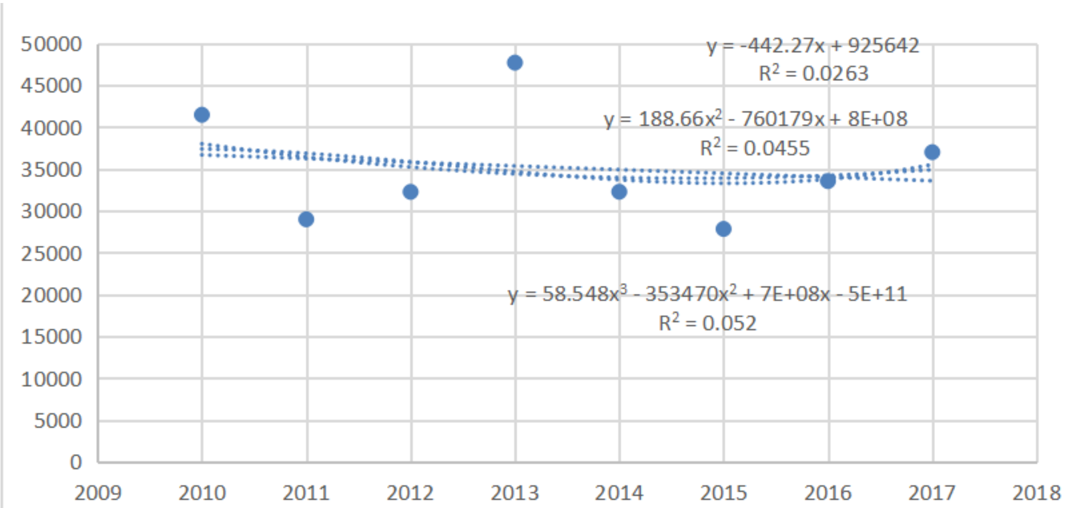


Figure 10 the fit between the annual consumption of VA and time (year)

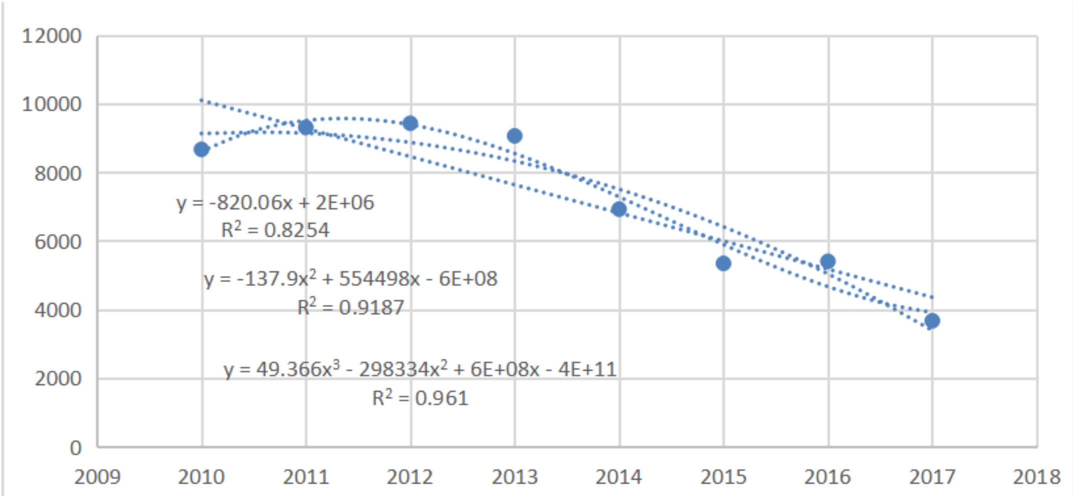


Figure 11 the fit between the annual consumption of WV and time (year)

As can be seen from Figure 4, from 2007 to 2010, the annual total consumption of VA state drug reports showed a fluctuating growth trend. The fitted model can be used to present the corresponding relationship between the total number of drug reports and the year. In order to determine the more accurate relationship between the two, this paper conducts one, two, three fittings and determines an ideal Fitting model.

Once fitted model: $Y_1 = a_1 x + a_0$

According to the data in the appendix, the regression equation is obtained by Matlab fitting.

$$Y_1 = ax - a_1$$

Quadratic fitting model:

$$Y_2 = a_2 x^2 + a_1 x + a_0$$

According to the data in the appendix, the regression equation is obtained by Matlab fitting:

$$Y2 = b2\, x^2 + b1\, x + b0$$

Three-fitting model:

$$Y_3 = a_3 x^3 + a_2 x^2 + a_1 x + a_0$$

According to the data in the appendix, the regression equation is obtained by Matlab fitting:

$$Y = c3\, x^3 + c2\, x^2 + c1\, x + c0$$

The degree of polynomial is good or bad, so a curve with a small fitting error is selected. Calculate its residual standard deviation for each type of curve that is trial-calculated:

$$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(H_i - h_i)^2}$$

Where hi is the fitted value, Hi hi is the fitted dispersion, and the smaller the value of S, the better the fit of the curve, the corresponding curve

The line is the form you want to select. In addition to the residual standard deviation S, the goodness of fit R is also an indicator to measure the effect of the fitted curve on the original data. Goodness of fit:

$$R = \sqrt{1 - \frac{\sum_{i=1}^{n}(H_i - h_i)^2}{\sum_{i=1}^{n}(H_i - h_i)^2}}$$

Among them, the better the fitting goodness is, the better the curve fitting effect is. Consider the residual standard deviation S and the goodness of fit R to select the ideal curve type.

Table 1. the three-fit

| | One time fit | Quadratic fitting | Three-time fit |
|---|---|---|---|
| R | 0.81 | 0.88 | 0.95 |

According to the above table, the standard deviation of the three-fit is the smallest, and the goodness of fit is closest to 1, so we use the cubic fitting model.

We re-predicted the predicted total number of drug reports, and the results are shown in the table below:

Table 2. Forecast of total VA drug count in the next 5 years

| **Year** | **Drug report total forecast** |
|---|---|
| 2014 | 32265 |
| 2015 | 27819 |
| 2016 | 33539 |
| 2017 | 36994 |
| 2018 | 34876.54 |
| 2019 | 34103.03 |
| 2020 | 34513.52 |

**4.2 Establish a grey forecasting model to predict consumption to 2018, 2019, and 2020**

In order to estimate synthetic opioids and heroin events (cases) and to study their trends, we need a grey prediction model is established based on the conditions given by the title and the calculated data. The specific steps of the model to solve the problem are as follows :( taking PA State as an example):

Definition:n =1, 2, 3, 4, 5, 6, 7 , 8

1 represents 2010, 2 stands for 2011, 3 stands for 2012, 4 stands for 2013, 5 stands for 2014, 6 stands for 2015, 7 stands for 2016, and 8 stands for 2017.

Step 1:: the ratio test

The time series for establishing the total number of drug reports is as follows:

X(0)=(89981, 86793,78577, 72096, 77318, 75351, 72376, 68751)

The ratio of the predicted total number of drug reports

λ(k)=, k=2,3,4,5,6,7,8

λ=(λ(2), λ(3), λ(4), λ(5), λ(6), λ(7), λ(8))=(1.0367, 1.1046, 1.0899, 0.9324, 1.0261, 1.0411, 1.0527)

Judging the ratio of the predicted value of the total number of drug reports

Since all λ(k)∈[0.9324,1.1046], K=2,3,4,5,6,7,8.

Therefore, it can be used as a satisfactory modeling of GM (1, 1).

Step 2: the establishment of the GM (1,1) test model

Make an accumulation of the raw data X(0) (that is, the 7 counts of the total number of drug reports)

$$x^{(1)}(i) = \sum_{k=1}^{i} x^{(0)}(k)$$

X(1)(1)=X(0)(1), i=2,3,...,8

X(1)=(X(1)(1),X(1)(2), ...,X(1)(8))=(89981,176774,263567,342144,414240,491558,563934,632685)

Take the weighted mean sequence of X(1):

$$z^{(1)}(k) = ax^{(1)}(k) + (1-a)x^{(1)}(k-1)$$, K=2,3,...,8

Where a is a determining parameter.

Thus, the galvanic differential equation model of GM(1,1) is:

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

Among them, a is the development of gray scale, and b is the endogenous control gray scale.

The corresponding grey differential equation is:

$$x^{(0)}(k) + az^{(1)}(k) = b \quad ,k=2,3,...,8$$

Construct data matrix B and data vector Y

$$Y = B(a,b)^T$$

Estimated value of the parameter obtained by least squares

$$(\hat{a},\hat{b})^T = (B^T B)^{-1} B^T Y$$

So there are special solutions:

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

Step 3:The third step is to solve the model.

Coverable interval $\in (e^{-\frac{2}{n+2}}, e^{\frac{2}{n+2}})$

Therefore, all the ratios of x(0) are in the coverageable range. After testing, it is appropriate to take the parameter α=0.5 here, so there are:

Z(1)=(133377.5,220170.5,302855.5,378192,452899,527746,598309.5)

Step 4:The fourth step is to test the model

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

## 5. Conclusions of the problem

After testing, the impact of our project on heroin crimes is heterogeneous, depending on the per capita prescription of opioids before the county policies. In the opioid-intensive counties, heroin crimes fell by 49-89%.

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