An Analysis of Macro Effects of Drunk Driving Penalty on Motor Vehicle Traffic Accidents in China

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Abstract. The effects of the law to punish drunk driving after coming into force in China can be seen in some media reports, while academic statistical analysis and evaluation are rare. In this study, the intervention analysis model of the law was constructed, by which the data of the number of motor vehicle accidents per 10,000 people in China, the number of injuries per 10,000 people and the number of deaths per 10,000 people were fitted, the macro effects of "drunk driving in punishment" on motor vehicle accidents in China were analyzed. The results showed that "drunk driving penalty" did not change the trend of motor vehicle accidents in China statistically.

1. Introduction
Driving under influence (DUI), speeding, overloading, driving without license and fatigue driving are listed as the "five killers" of the road, among which "DUI" ranks first. The cases, such as Hu Bin's car racing case in Hangzhou, Sun Weiming's DUI case in Chengdu and Zhang Mingbao's DUI case in Nanjing, with the labels of "rich second generation" and "luxury cars" attached to and the tragic scenes caused by the accident, have been extensively reported in the national media and become the focus of national public opinion. Strong public opinion plays an important role in promoting the legislation of dangerous driving crime. Amendment VIII to the criminal law of the People's Republic of China was adopted and promulgated at the 19th meeting of the Standing Committee of the Eleventh National People's Congress of the people's Republic of China on February 25, 2011, and shall come into force as of May 1, 2011. "Dangerous driving crime" added in "Amendment VIII" has written "DUI" into the criminal law, which means "DUI penalty" has officially come into force.

After "DUI penalty", the number of traffic accidents, deaths and injuries related to alcohol decreased significantly compared with the same period before "DUI penalty ". Moreover, before "added into the penalty", there were all ages and professions in the "DUI" group, even professional drivers such as taxi drivers. After " added into the penalty", the "DUI group" also changed significantly, and the number of professional drivers' DUI was greatly reduced. There is no doubt that the restraining effect of "DUI penalty" on "DUI" behavior is significant, which meets people's general psychological expectation to improve the traffic safety under the public opinion that "DUI is stronger than tiger". Furthermore, it is also a good wish and expectation of people to exert a good influence on the change trend of the total amount of traffic accidents in our country through the "DUI penalty". So, to see whether the facts do what people want, this study constructs the intervention analysis model of "DUI penalty" to fit the data of the number of motor vehicle traffic accidents per 10000 people, the number of injuries per 10000 people, and the number of deaths per 10000 people in China, and analyzes the macro effect of "DUI penalty" on motor vehicle traffic accidents in China. The effect of...
"DUI penalty" can be seen in some media reports, but academic statistical analysis and evaluation are rare.

Intervention here refers to the occurrence of external events relative to time series, such as natural disasters, man-made disasters, the implementation of major political or economic policy measures, the promulgation of new laws, strikes, sales promotion, advertising and so on [4]. Intervention analysis is a very useful technique [5] when exogenous intervention occurs in time series.

The literature on the impact assessment after the occurrence of major natural and political events or the effect analysis after the implementation of certain laws or regulations has been very rich and covers a wide range of fields. For example, Castillo Manzano J I and others evaluated the effectiveness of a series of control policies implemented to reduce the death rate of traffic accidents after the eastern expansion of the European Union. The research found that: policies that effectively reduce alcohol consumption among young drivers improve road safety; the policy of "zero tolerance for alcohol" is not a panacea, because countries with the most restrictive policies do not achieve better results of road safety; the correlation between male drinking and traffic accident deaths is significant [6]. The study of Melberg H O et al. answered the controversy of whether the ban on smoking in Norwegian restaurants and bars would reduce the income of the hotel industry. They used the intervention analysis model and found that the ban on smoking has no statistically significant long-term impact on the income of restaurants and bars [7]. Enders W et al. evaluated the effectiveness of the policy of preventing terrorist events implemented from January 5, 1973 to April 15, 1986, and proved that installing metal detectors in airports is an effective measure, while the retaliatory attack of the United States on Libya does not reduce the terrorist attacks against Britain and the United States as hoped, but immediately increases the number of "terrorist attacks" by 38 [8]. Gyllenberg F et al. evaluated the effect of a public project to provide free long-acting reversible contraceptive methods. Through time series analysis from 2000 to 2015, the implementation of this project reduced the abortion rate in Vantaa area of Finland by 16% in people aged 15 to 19 and 36% in people aged 20 to 24 [9].

Due to the different research purposes, scope and data types, the above literature adopts different measurement models and methods, such as ARIMA-based intervention analysis model [4,7,8], panel data model [6], transfer function model [8], survival analysis, logistic regression analysis [10], etc. Considering that the main purpose of this study is to investigate whether "DUI penalty" has changed the trend of total traffic index of motor vehicles, a more direct and simple modeling method is adopted to establish an intervention analysis model based on the log-linear regression model.

2. Variable selection and corresponding symbol

The data in this paper are from the official website of the National Bureau of Statistics [national data: http://data.stats.gov.cn]. The annual data from 1996 to 2017 are used in this study. In order to make the number of motor vehicle traffic accidents more reasonable and objective, the existing literature [6] is used for reference in this study. The total number of motor vehicle traffic accidents in China is represented by the number of accidents per 10000 people, and the three traffic accident indicators in Table 1 are used to characterize the basic situation of the total number of motor vehicle traffic accidents in China. Table 2 shows the corresponding relation between the value of variable $t$ in the model and the year, and the original data can be seen in the appendix.

| Table 1 Variable and symbols of vehicle traffic accident |
|---------------------------------------------------------|
| The number of motor vehicle accidents per 10,000 people in China | The number of injuries per 10000 people in China's motor vehicle traffic accidents | The number of deaths per 10000 people in China's motor vehicle traffic accidents |
| $f s_t$ | $ss_t$ | $sw_t$ |
### Table 2 Corresponding table of variable $t$ and year

| Year | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|------|------|------|------|------|------|------|------|------|------|------|------|
| $t$  | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   |
| Year | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| $t$  | 12   | 13   | 14   | 15   | 16   | 17   | 18   | 19   | 20   | 21   | 22   |

3. Research method

In China shows a trend of increasing first and then decreasing in the sample period. It reaches the highest value in 2011, and then enters the declining stage. This reflects the change between the inducing factors and the restraining factors of traffic accidents in the game process. It can be seen from the asymmetry of rising and falling trends that the time series before and after 2012 come from different data generation processes.

This study is concerned about whether the overall decline trend of the time series after 2012 is affected by the intervention of "DUI penalty" implemented in May 2011, and whether the intervention has an "ideal" promoting effect on the existing decline trend. Observing the sequential growth rate of the number of incidents (see Figure 1 (b)), it is found that in the declining region from 2002 to 2017, the average annual growth rate after the implementation of "DUI penalty" has not decreased, but increased compared with the previous one. So, it leaves a problem that if there is any statistical significance in this difference.

For this purpose, the sample data are fitted with the following "log-linear" regression model,

$$\ln(f_{st}) = \beta_0 + \beta_1 t + \beta_2 D_{11} * t + u_t$$

$D_{11}$ is a dummy variable. In order to investigate the annual change trend of growth rate, the multiplication mode of dummy independent variable is adopted here. Since the implementation of "DUI penalty" in China was in May 2011, 2011 is the interference time point. However, when it was implemented, there was nearly half a year passed, so the dummy variables are set as follows:

$$D_{11} = \begin{cases} 
0.5, & t = 2011 \\
1, & 2011 < t \leq 2017 \\
0, & 2001 < t < 2011 
\end{cases}$$

Due to the inherent autocorrelation of time series, $\{u_t\}$ may be a stationary non-white noise series.
with zero mean value, which does not meet the classical assumption of least square estimation, so the
test of regression model is no longer reliable. For this reason, ARMA model is used to fit \{u_t\}, i.e.
\[ u_t = \frac{1+\theta(L)}{1-\phi(L)} \varepsilon_t, \]
where \( L \) is lag operator and \( \theta(L) \) and \( \phi(L) \) are lag operator polynomials.
\[ \theta(L) = \theta_1 L + \theta_2 L^2 + \cdots + \theta_q L^q \]
\[ \phi(L) = \phi_1 L + \phi_2 L^2 + \cdots + \phi_p L^p \]
\( \{\varepsilon_t\} \) is white noise sequence.
After fitting the data with the model, the sample regression equation is obtained (see model 1).
If \( \beta_1 \) and \( \beta_2 \) pass the significance test of parameters, then
The average annual growth rate before "DUI penalty" is: \( \beta_1 \)
The average annual growth rate after "DUI penalty" is: \( \beta_1 + \beta_2 \)
If \( \beta_1 \) passes the significance test of the parameter but \( \beta_2 \) doesn't, then
The average annual growth rate before and after "DUI penalty" is: \( \beta_1 \)
To sum up, the analysis model to test whether "DUI penalty" has intervention effect on the change
trend of the number of motor vehicle traffic accidents in China is as follows:
\[
\begin{align*}
\ln(f_s_t) &= \beta_0 + \beta_1 t + \beta_2 D_{11} \ast t + u_t \\
u_t &= \frac{1+\theta(L)}{1-\phi(L)} \varepsilon_t
\end{align*}
\]
Model 1
It can be seen from Figure 2 [a] that the number of injuries per 10000 people in China's motor
vehicle traffic accidents has entered a declining stage since 2002. In this stage, the annual average
growth rate after the implementation of "DUI penalty" is slightly higher than that before (see Figure 2
(b)); the number of deaths per 10000 people in China's motor vehicle traffic accidents has entered a
decreasing stage since 2005 (see Figure 3 (a)), and the annual average growth rate between 2005 and
2010 is lower than that between 2011 and 2017 after the implementation of "DUI penalty" (see Figure
3 (b)). This result is not consistent with the expectation or intuition that "DUI penalty" will curb
the total number of motor vehicle traffic accidents and boost the existing declining trend. To find out
whether "DUI penalty" interferes with the development trend of the number of injuries and deaths per
10000 people in China's motor vehicle traffic accidents, this study continues to build model 2 and
model 3 along the method as model 1 to test whether the difference is statistically significant.
\[
\begin{align*}
\ln(s_s_t) &= \beta_0 + \beta_1 t + \beta_2 D_{11} \ast t + u_t \\
u_t &= \frac{1+\theta(L)}{1-\phi(L)} \varepsilon_t
\end{align*}
\]
Model 2
\[
\begin{align*}
\ln(s_w_t) &= \beta_0 + \beta_1 t + \beta_2 D_{11} \ast t + u_t \\
u_t &= \frac{1+\theta(L)}{1-\phi(L)} \varepsilon_t
\end{align*}
\]
Model 3

![Figure 2 (a) A sequence diagram of the number of injuries per 10,000 people in motor vehicle accidents](image-url)
4. Empirical study and conclusion

The sample regression equation of model $\ln(f_\text{s}_t) = \beta_0 + \beta_1 t + \beta_2 D_{11} \ast t + \epsilon_t$ is:

$$\ln\left(\hat{f}_\text{s}_t\right) = 2.608270 - 0.146287 t + 0.027816 D_{11} \ast t + \hat{\epsilon}_t.$$
Figure 4 Autocorrelogram and partial autocorrelogram of residual sequence \{\hat{u}_t\}

It can be seen from Figure 4 that there is a significant first-order autocorrelation in the residual sequence \{\hat{u}_t\}, and the ARMA model is fitted to eliminate its autocorrelation. After repeated attempts and comparison, considering the goodness of fit and information value, it is confirmed that \{\hat{u}_t\} is generated in a MA [1,5,6] process. The final fitting model can be seen in "accident number model" in Table 3.

In the same way and process, the sample regression equations of model 2 and model 3 can be obtained (see Table 3). It can be seen from the correlation graph [Figure 5 (a)] of residuals of model 1 that the autocorrelation coefficient and partial autocorrelation coefficient of each delay period number of residual sequences are within the range of double standard deviation, and the p-value of adjoint probability of the sample realization value of Q statistic tested shows that for each delay period number m, the original assumption that the autocorrelation coefficient of residuals is zero cannot be rejected. Therefore, the residual sequence \{\hat{\epsilon}_t\} with the zero mean value is a white noise sequence, indicating that model 1 extracts most of the data information and fits the sample data well (see Figure 5 (b)).

Figure 5(a) Autocorrelogram and partial autocorrelogram of the residual \{\hat{\epsilon}_t\} of "accident occurrence number model"
Figure 5(b) The sequence diagram of fitting value and actual value of "accident occurrence number model" and residual sequence

Figure 6(a) Autocorrelogram and partial autocorrelogram of the residual $\{\hat{\varepsilon}_t\}$ of "accident injury number model"

Figure 6(b) The sequence diagram of fitting value and actual value of "accident occurrence number model" and residual sequence
Figure 7(a) Autocorrelogram and partial autocorrelogram of residual $\{\hat{\varepsilon}_i\}$ of "accident death number model"

Figure 7(b) The time sequence diagram of fitting value and actual value of "accident death number model" and residual sequence

Similarly, it can be seen from Figure 6 and Figure 7 that the residual sequences of model 2 and model 3 are all white noise, indicating that the model has a good fit to the data. In addition, the goodness of fit and information value of the three models in Table 3 also show the good results of model selection and optimization.

Table 3 The report of sample regression equation

| Content                  | Accident number model [model 1] | Accident injury number model [model 2] | Accident death number model [model 3] |
|--------------------------|---------------------------------|----------------------------------------|---------------------------------------|
| Coefficient of independent variable | C  | 1.491803 [p=0.0001] | 1.848312 [p=0.0000] | ★                                      |
|                          | t  | -0.064329 [p=0.0008] | -0.075530 [p=0.0000] | -0.043815 [p=0.0000]                   |
|                          | t*D11 | ★                                      | ★                                      | ★                                      |
|                          | AR[1] | ★                                      | 0.730670 [p=0.0122] | 1.414557 [p=0.0001]                   |
| AR[2] | MA[1] | MA[2]t | Ma[3] | Ma[4] | Ma[5] | MA[6] | R²   | R²   | R²   |
|-------|-------|--------|-------|-------|-------|-------|------|------|------|
|       | 1.137847 [p=0.0000] | 0.115964 [p=0.0000] |       |       | -1.073131 [p=0.0000] | -0.935270 [p=0.0000] | 0.988499 | 0.984317 | 0.984317 |
|       |       |        |       |       |       |       | 0.982778 | 0.978473 | 0.978473 |
|       |       |        |       |       |       |       | 0.987304 | 0.983496 | 0.983496 |

Note: ★ indicates that the item has not passed the significance test with a significance level of 0.05 and has been eliminated, or the coefficient of t is no longer significant caused by the item and does not set the item; p-value in brackets indicates the adjacent probability of the sample realization value of the test statistic.

In the declining area, in the three sample regression equations (see Table 3), the coefficients of t pass the significance test at a very high significance level, while the coefficients of the dummy variable term t * D11 fail the significance test, indicating that "DUI penalty" does not change the annual average growth rate of "number of accidents per 10000 people", "number of injuries per 10000 people" and "number of deaths per 10000 people". That is to say, "DUI penalty" has not interfered with the change trend of China's motor vehicle traffic accidents.

5. Thinking and discussion

The empirical results show that the impact of "DUI penalty" on the overall trend of traffic accidents in China is partial and non-decisive. This is also determined by the occurrence mechanism of traffic accidents. The occurrence of traffic accidents is the result of mutual penetration and causality of the four elements of people, cars, roads and environment, and people, cars, roads and environment are restricted by the overall civilization and development level of the country. Therefore, the prevention and control of traffic accidents need the cooperation of government, society and individual citizens, and the participation and effective integration of multiple subjects and resources.

To some extent, the empirical results reflect the fact that although DUI is listed as the top five killers, "DUI" are not the first causes of traffic accidents. "DUI" does not rank among the top 10 causes of death in traffic accidents. According to the data of 2011, there are 3555 traffic accidents and 1220 deaths caused by DUI in China, which is far lower than the deaths caused by dog biting because
of poor supervision [2, 13]; from the proportion of pedestrian deaths caused by scraping in 2006-2012, the proportion of DUI only accounts for 5.03%, ranking sixth among many reasons [14].

The empirical results also reflect the necessity and importance of legal personage's thinking, discussing and arguing about "DUI penalty" from another perspective. For example, Song Yu and others think that "DUI penalty" is not consistent with the principle of modesty and restraint in criminal law, and its "one size fits all" approach is contrary to the principle of criminal law [15]; Xie Yongzhao and others call for the criminal treatment of "DUI" crime to be placed in the legal space and handled by legal thinking to avoid the short-term emotional criminal legislation and to give full play to the normal function of law setting; Zhou Xiang thinks that merely criminalizing DUI and racing will lead to the vacancy or conflict of the relevant administrative law, which is against the constitution. We can prevent and control dangerous driving by improving the intensity of administrative enforcement, perfecting the existing administrative law and reasonably interpreting the current criminal law.

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