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ANALYSIS ON LONG-TERM RELATIONSHIP BETWEEN ECONOMIC GROWTH AND MORTALITY FROM TRAFFIC ACCIDENT

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ABSTRACT

In this paper we investigate the long-term relationship between the economic growth in China and the number of people who died in traffic accident by using the time series data in the period from 1990 to 2008 in China. Our study found an inverted U-shaped relationship between the economic growth and the number of people who were killed in traffic accidents. The number of death in traffic accidents increased with the development of economy in early stage. However, as the economy has been developed into certain level, the mortality rate of the traffic accidents start to decrease, which clearly indicates that the Smeed's law can also be applied in China. Besides the level of economic development, we also analyses some other factors that may influence traffic accidents. These factors can either accelerate or decelerate the inverted U-shape relationship.

Keywords: *Economic Growth, Traffic Accidents, Smeed's Law*

1. INTRODUCTION

China has achieved widely acknowledged progresses of economic development during past 30 years. The GDP in China has been increased from 364.52 billion RMB in 1978 to 30067 billion RMB in 2008. As the economy developed rapidly, the level of household consumption also surged. The consumption of durable goods occupied a large portion of the total consumption expenditure. The number of auto owned by civilian has been increased from 1.3584 million in 1978 to 50.9961 million in 2008, which is almost 38 times of the number in 1978. Although the rapid increase of personal vehicles have greatly facilitated people, however, it has caused many problems such as road congestion and traffic accidents as well. The mortality of traffic accidents in China in 1990 is 49243 and reached its peak of 109381 in 2002 and decreased then. The number of mortality dropped to 73484 in 2008. Accordingly, we can discover that the mortality increased with the increase of number of autos in China firstly and then dropped after reaching its peak. According to the statistics of world health organization in 2007, the mortality of traffic accidents in China ranked first among all countries in the world in 2007 and was much higher than any other country. Therefore, thoroughly studying the relationship between economic growth in China and the traffic mortality is of profound and meaningful significance: On one hand, China faces strong pressure to improve its traffic condition compared with many other countries in the world; On the other hand, the study of traffic accidents in our country has just started up while the research of traffic accidents has been continued for several decades in many other countries. By encouraging and leading the universities and research institutes in our country to conduct research in this field, a more mature and integrated solution can be formed to solve today's traffic problems in China.

Previous studies on traffic accidents in China are mainly confined to the situation of traffic accidents of some certain provinces or cities. However, few researches are conducted to study the relationship between economic growth and the traffic accidents mortality on the whole country scale. Based on the results of some previous studies, I used the traffic accidents data in China to verify whether there exists an inverted U

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relationship between economic growth and traffic accidents.

In Section 2, we review and introduce some previous literatures which studied the relationship between economic growth and traffic accidents. Section 3 presents data and analysis, we briefly describe the sample data and analyze them statistically. Section 4 is model and test, we mainly adopt negative binomial distribution model to verify the inverted U shape relationship between the Chinese economic growth and the traffic accidents. Section 5 concludes.

2. LITERATURE REVIEW

In regard to the long term relationship between traffic accidents and the number of autos, the British statistician and road safety expert R.J.Smeed is the first one who conducted researches in this field. R.J.Smeed [1] pointed out that in countries including the United States and New Zealand, the traffic accidents mortality increased with the growing number of automobiles at first, then, after the traffic accidents mortality increased to a certain high point, it began to decrease gradually. R.J.Smeed proposed two viewpoints regarding to this phenomenon: First of all, people are suggested to take necessary safety measures to traffic. Secondly, he believes that there exists a 'National learning curve' which helps improve the situation of traffic accidents. As the whole population as well as the number of cars grows rapidly, people are trying all kinds of approaches to tackle the road safety problems such as building more highways of higher quality, formulating better laws and regulations of traffics and encouraging car manufactures to produce safer cars. Therefore, even the number of cars continued to increase, the mortality of traffic accidents decreased after these adequate measures were taken. Later, people define the inverted U shape relationship between number of cars and the traffic accidents mortality rate, which is very similar to the inverted U shape curve between the extent of inequality of income and economic growth discovered by [6], as the Smeed's law.

Since Smeed disclosed the inverted U shape curve of traffic accidents mortality rate, many scholars and experts continued to conduct a lot of in depth researches regarding the relationship between economic growth and traffic accidents. Teik Hua Law [5] tend to suggests that the inverted U shape curve of traffic accidents mortality can be explained by two kinds of effect: the first effect is called the scale effect of income growth. In this case, with the development of economy, people's demand of cars and transportation services is ever increasing. Thereafter, the number of people who died in traffic accidents increased with the increases of income because of the scale effect. The second effect is called the substitution effect. In the early stages of economic development, the number of death caused by traffic accidents was due to threaten of increasing number of cars imposed on pedestrians. However, as the personal income keep on increasing which enabled more and more pedestrians owned their own cars. This way the growing number of cars will in fact decrease the mortality of traffic accidents. Moreover, Teik Hua Law [5] further pointed out that the turning point of the inverted U shape curve cannot be achieved automatically, but requires the guide of national policy and the influence of national learning curve.

Antonio Garcia—Ferrer [2] thinks that the traffic accidents cycle is closely associated with the economic growth. Antonio Garcia—Ferrer(2007) used quarterly data and annual data respectively to analyze the relationship between the Spanish traffic accidents cycle and its real economic activity cycle. Antonio Garcia—Ferrer based on the assumption that the traffic accidents rate is determined by the number of cars and some other exogenous variables and that the level of economic activity influences the number of cars possessed, to reflect the situation of traffic accidents by using data concerning the number of traffic accidents, the number of injuries in traffic accidents and the mortality of traffic accidents. The level of economic activity is represented by industrial production index and the number of cars newly registered. To describe the cyclical changes of the abovementioned variables respectively, the result indicates that the traffic accidents cycle coincides with the real economic activity cycle. The traffic accidents rate becomes higher in the period of economic prosperity. Ulf-G. Gerdtham(2002) reached a similar result in his study, Ulf-G. [3] used the aggregate economic data of 23 member countries of OECD from 1960 to 1997 to analyze the relationship between the macroeconomic situation and the mortality rate. The research discovered that as the economy of a country develops steadily, the mortality rate of the country also increases. Notably, the mortality rate of traffic accidents increases 0.8% with every 1% drop in unemployment rate. What's more, the research result of David Bishai(2006) informed us that in countries with low income(GDP/Capita<$1600),the mortality of traffic accidents increases 3.1% with every 10% increase in GDP growth.

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Compared with the previous studies mainly concentrate on the verification of the inverted U shape relationship between economic growth and the traffic accidents, Nejat Anbarci(2007) on the other hand first analyze the relationship between traffic accidents and the inequality of income distribution. Nejat Anbarci(2007) think that although the level of income of a country is a crucial factor that determines the mortality rate of traffic accidents, it is defective to simply analyze the relationship between the national income and the traffic accidents mortality rate. He point out that when the national income of two countries are very similar, the mortality rate of traffic accidents in those two countries can still vary greatly because of the different extent of inequality of income distribution in these two countries. Accordingly, the distribution of national income is a crucial determinant of traffic accidents mortality of a country. Nejat Anbarci(2007) derive the research result through empirical analysis: the higher the extent of inequality of national income distribution, the higher the mortality rate of traffic accidents in a country. That is, the inequality of income distribution has negative externalities. On the one hand, cars are classified as luxury goods and the inequality of income distribution actually increase the number of private cars; On the other hand, for those who are not able to afford to buy a car has to choose to walk or to ride a bicycle or motorcycle as means of transportation, they are more likely to be the victims of the traffic accidents.

Leonard J.Paulozzi for the first time category the mortality of traffic accidents according to their means of transportation, they are pedestrians, bicycle riders, motorcycle riders, car owners ,etc. Leonard J.Paulozzi [8] analyzes the relationships between the number of mortality of the abovementioned five kinds of road users and the level of economic development. He found out that as the economy is in the early stage of development, most of the mortality is consisted by pedestrians, bicycle riders and motorcycle riders. However, as the economy becomes highly developed, car drivers occupied a great portion of the mortality of the traffic accidents. Furthermore, of all the abovementioned five kinds of road users, there is a U shape relation between mortality rate and the economic growth for all of them except the bicycle riders and motorcycle riders. The explanation given by Leonard J.Paulozzi(2007) on this phenomenon is that : Regardless of bicycle riders or motorcycle riders, it is possible for them to choose to ride bicycle or motorcycle not in the economic consideration. In developed countries, bicycles and motorcycles are no longer simply a means of transportation; they have become a way of leisure life. Thus, even the economy of a country is keeping on developing, bicycles and motorcycles will not be fully replaced by cars.

As the number of death caused by traffic accidents has kept on increasing all around the world, most of the countries have promulgated laws concerning traffic safety or design policies that may alleviate the traffic accidents rate. However, whether these laws or policies will function effectively is still depend on whether these laws or policies can be executed thoroughly and objectively. In fact, whether the policies or laws can be executed thoroughly and objectively is largely determined by the political institution of the country----which helps ensure the integrity and probity of the government as well as the legal system. Subsequently, [9] and [10] analyzes the influence of the extent of corruption of the public sector on traffic accidents mortality. [4] and [7] classified the influence of corruption into two categories, direct influence and indirect influence. The direct influences mainly refer to the fact that perpetrators can avoid being punished by bribing the law executors. Therefore, the more serious the extent of corruption the higher mortality rate can be, because laws cannot be executed effectively; On the other hand, the indirect influence of corruption on traffic accidents actually stimulate more and more people to put the social resources in rent-seeking, which is unproductive and will in turn cause the government lack the adequate input of improving traffic. In this way, more people will die in traffic accidents either.

In China, scholars who started off researches in this area comparatively early are Zhou and Lu of the Transportation Institute of Tsinghua University. By analyzing the regular pattern of social development and traffic accidents, Zhou (2006) used statistics from several nations to verify the model proposed by Smeed and found that Smeed's law is valid in the motorized early stages; Zhou (2006) suggest that the pattern of traffic accidents trends affecting by a series of joint forces can be characterized as rising period, peak period, falling period, fluctuation period and stable period. Taking the statistics of Chinese traffic accidents and the extent of motorization into consideration, Zhou (2006) arrive at the conclusion that China is still on the rising period track.

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3. DATA AND DESCRIPTIVE ANALYSIS

(1) Sample selection

As the data concerning traffic accidents condition was included in the statistical yearbook since 1990, the sample data used in this paper is the aggregate data of traffic accidents from 1990 to 2008 and the resource of our data is from <Chinese statistical yearbook>. As automobile is the major cause of traffic accidents, we choose all the cars owned by private owners in the country to explain its influences on traffic accidents. Besides, we choose the GDP per capita from 1990 to 2008 to measure the economic growth in China.

From figure 1 we can see that the number of people killed by traffic accidents raised gradually with the increase of the economic growth. The peak of the mortality of traffic accidents， which is 109381, was reached in 2002. The mortality then began to decline in the following years. On the other hand, the ownerships of private cars are positively correlated with the gross national product. In another word, as the level of economy have become more and more advanced, the ownership of private cars also increased very rapidly. We find out that the number of people who died in traffic accidents is not positively correlated with the ownership of private cars. In fact, although the mortality of traffic accidents will increase as the number of autos increases within our country, it will not increase unlimitedly.

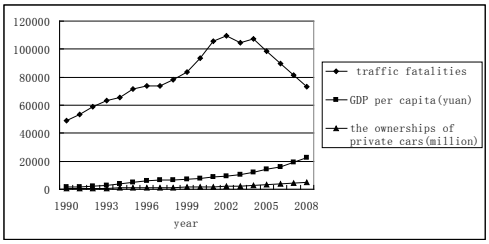

Figure 1 The Number Of Traffic Fatalities Nationwide

(2) The selection of variables

In this paper, we also introduce a set of variables that will influence the mortality of traffic accidents besides the number of ownerships of automobiles. Generally, the medical standard of a country can exert a very significant influence on the traffic accident mortality and we can expect that the mortality will decline with the development of medical treatment. Thereafter, we choose the number of health professionals as the proxy variable. The health professionals can be classified as doctors, registered nurses, pharmacist and inspectors.

According to the statistics data, the number of traffic accidents occurred in cities is smaller than the number of traffic accidents happened in suburbs and counties. There are two alternative explanations of this phenomenon: the first one is that the level of urbanization of China is still not very high so that the urban population is smaller than the suburban population on the whole. On the other hand, it is because that the traffic order of cities is often much better than the traffic order of counties as the cost of violating traffic order can be very high in cities.

In order to include the influences of income distribution on traffic accidents, the paper include the Gini coefficient in our explanatory variables. As auto is still belong to luxury goods in China, the distribution of income in our country still play a very crucial role in influencing the ownerships of private cars which determine the number of traffic accidents. It is necessary to expect that the more unfair the distribution of income, the less possible for people to own their own cars. For those who are not able to afford a car, they have to choose to walk, to ride a bicycle, to ride a motorcycle or to take a bus as their way of transportation. It is these people that are most likely to become the victims of traffic accidents.

Moreover, drunk driving is one important cause of traffic accidents. According to an accident investigation of world health organization in 2008, about 50%---60% of all traffic accidents is related to drunk driving which has already been identified as the paramount cause of traffic accidents. In China, the number of traffic accidents caused by drunk driving can be as high as tens of thousands every year and over half of the traffic accidents which caused deaths are closely related drunk driving. The paper introduces the amount of alcohol consumed by every household per person in both cities and counties to test the relationship between drinking and traffic accidents. The total consumption of alcohol includes the consumption of white spirit, beers and ratafee.

On October 28, 2003, the fifth meeting of standing committee of national people's congress passed the legislation of < the road safety law of people republic of China>. In order to test the influences of the road safety law legislated in 2003 on the traffic accidents in our country, this paper added a variable intercept of time T, which remain 0 from 1990-2003, and enact as 1 after 2004.

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4. MODEL

As the number of traffic accidents and the mortality of traffic accidents are all discrete variables and all of them are non-negative integers, therefore the Poisson distribution can be appropriately applied to analyze this count data. However, as one of the prerequisites of Poisson distribution is that the conditional mean function equals to the variance function, this prerequisite is often considered as a major drawbacks of Poisson regression model. This is because for all data that are overly spread, the requirement that the variable mean equals to s variance is too strict. Based on this drawback of Poisson distribution, the negative binomial regression model is proposed which slack the assumption that the variable mean equals to its variance.

The basic equation of Poisson distribution is:

$$\Pr ob(Y_{it} = y_{it}) = e^{-\lambda_{it}} \lambda_{it}^{y_{it}} / y_{it}!, y_{it} = 0,1,2,\cdots, \quad (1)$$

In this equation, y_{it} is extracted from the numbers which parameter is λ_{it} and comply to the Poisson distribution， and λ_{it} is correlated to the explanatory X_{it} .The expression of parameter λ_{it} is $\lambda_{it} = \exp(\beta_i X_{it})$. According to the features of Poisson distribution, we can prove:

$$E(y_{it}|X_{it}) = Var(y_{it}|X_{it}) = \lambda_{it} = \exp(\beta_i X_{it}) \quad (2)$$

The maximum likelihood of parameter β obtained by maximizing the log-likelihood function：

$$\ln L(\beta) = \sum_{i=1}^{N}\sum_{t=1}^{T}(-\lambda_{it} + y_{it} X_{it}^{'} \beta_i - \ln(y_{it}!)) \quad (3)$$

The negative binomial model is obtained from the heterogeneous cross section representation and to construct the negative binomial model and by introducing the deviation of gamma distribution, we can reconstruct the Poisson distribution as: $\lambda_{it} = \exp(\beta_i X_{it} + \mu_{it})$ .Where μ_{it} is the unobserved effect of individual samples, assume that the deviation $\exp(\mu_{it})$ comply to the Gamma distribution $(1,\delta)$, and is iid, at this time y_{it} is comply to the negative binomial distribution:

$$\Pr ob(Y_{it} = y_{it}) = \frac{\Gamma(\lambda_{it} + y_{it})\delta^{\lambda_{it}}}{\Gamma(\lambda_{it})\Gamma(y_{it}+1)(1+\delta)^{(\lambda_{it}+y_{it})}} \quad (4)$$

At this time, the conditional mean and conditional variance is $E(y_{it} \mid X_{it}) = \lambda_{it}$ and $Var(y_{it} \mid X_{it}) = (1+\delta/\delta)\lambda_{it}$. Apparently, as δ is any non-zero constant, conditional variance is larger than conditional means; As $\delta \to \infty$, negative binomial distribution converges to the Poisson distribution model and thus the negative binomial distribution is just a special case of Poisson distribution. The estimation of parameter β and δ , can be obtained by the following maximum likelihood function of negative binomial:

$$\ln L(\beta) = \sum_{i=1}^{N}\sum_{t=1}^{T}(\ln\Gamma(\lambda_{it} + y_{it}) - \ln\Gamma(\lambda_{it}) - \ln\Gamma(y_{it}+1) + \lambda_{it}\ln(\delta) - (\lambda_{it} + y_{it})\ln(1+\delta)) \quad (5)$$

As the introduction of $\exp(\mu_{it})$ permit that the conditional variance is larger than the conditional means, therefore the negative binomial distribution model can solve the problem of over dissemination of sample data.

As for Poisson distribution model, negative binomial distribution model and some other data count model, by using maximum likelihood estimation(quasi-MLEs), we can obtain the consistent estimator of parameters to be estimated. Besides, the consistence of Poisson QMLE does not require any additional assumption of y_i when given x_i . Even if the distribution is inappropriately assumed, Quasi-maximum likelihood estimator can still generate a consistent estimator which the conditional means is set correctly. For those distribution is incorrectly assumed, the maximum likelihood estimator of Poisson distribution is perfectly sound. Even the distribution is no longer Poisson distribution, it still keeps some features of effectiveness.

According to the abovementioned analysis and the approaches of some researches, this paper apply the time-series data from 1990-2008 to analyze the relationship between economic growth and the traffic accidents mortality in our country. This paper applies the QMLE estimation to estimate the time-series data:

Model1:

$$E(y_t \mid \alpha, X_t) = \exp\{\alpha + \beta_1 \ln(RJGDP_t) + \beta_2(\ln(RJGDP_t))^2 + \beta_3 X + \varepsilon_t\} \quad (6)$$

where y_t is the traffic accidents mortality in period t, $RJGDP_t$ is the GDP per capita of ten years, X is controlled variables which include the total ownerships of private autos(V), the number of health professionals(D), the total consumption of

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alcohol of every household per person for a whole year(W), Urban and suburban population ratio(UR), the Gini covariance in every year of China(G), and T is the intercept variable of time, deviation ε_t can be used to reflect the condition of traffic condition of road, weather as well as automotive safety which are elements that may influence the traffic accidents.

5. EMPIRICAL RESULTS

Using the aggregate data from 1990 to 2008 to estimate the result of model 1 illustrated in table 1 which the data included in the parenthesis is z estimator. From the result of estimation, there is an inverted U shape relationship between economic growth in our country and the traffic accidents mortality because we can observe that the coefficient of $\ln(GDP_t)$ is positive and the coefficient of $(\ln(GDP_t))^2$ is negative. This clearly indicate that the traffic accidents mortality is marginal diminishing with the increasing speed of economic growth and thus the mortality of traffic accidents will decline after reaching its turning point. This turning point will appear when GDP per capita is 11971 RMB according to model A and 8027 RMB according to model B. According to the statistics of model D, the traffic accidents mortality is positively correlated with the total consumption of alcohol per capita every year, the urban and suburban population ratio and the Gini coefficient and is negatively correlated with the total ownerships of private automobiles and the number of all health professionals. This result clearly coincides with the former expectation except the ownerships of private cars. Therefore, as the total consumption of alcohol, the total urban population and the Gini coefficient increases, the traffic accidents mortality will increase; On the other hand it will decrease if the standard of medical treatment improve. What's more, the execution of road safety law has not exerted a very significant influence on helping decrease the mortality of traffic accidents. We can find out that the coefficient of the time intercept variable of the total traffic accidents mortality is only -0.0161 compared with the traffic situation before the execution of road safety law in 2003. As for the total ownerships of cars, model derives a different regression result from model D. In model B, the traffic accidents mortality is positively correlated with the total ownerships and it is contrary in model D.

Table1 Regression Results Of Model 1

Explanatory variables	Model A	Model B	Model C	Model D
C	-5.0364(-44.78)	-25.8681(-115.37)	-4.6006(-30.42)	5.9593(72.90)
$\ln(RJGDP_t)$	3.5101(136.71)	7.1335(167.77)	3.4029(95.22)	5.9593(72.90)
$(\ln(RJGDP_t))^2$	-0.1869(-128.06)	-0.4690(-156.01)	-0.1803(-85.59)	-0.3306(-54.67)
$\ln(V_t)$		1.4924(107.67)		-1.1384(-23.21)
$\ln(D_t)$				-0.7820(-12.96)
$\ln(W_t)$				0.4253(8.3941)
UR_t				4.7228(66.26)
G_t				1.3870(16.92)
T			-0.0161(-4.3064)	-0.0039(-0.94)
$L(\beta)$	-10148.09	-4286.086	-10138.81	-943.5671
Adjusted R^2	0.6890	0.8731	0.6683	0.9585
Turning point (yuan)	11971	2008	12541	8207

The fact that the coefficient of the same variable in model B and model D is different and that the turning point calculated in model B is different from all the other three models indicate us that there exists Multicollinearity.It is highly possible that the total ownerships of autos, the GDP per capita, the total number of health professionals as well as the total consumption of alcohol per capital of each households may have the same time trend, that is , with the development of our economy, GDP per capita, the total ownerships of autos, and the number of health professionals across the country as well as the total consumption of alcohol per capita will also increase. To test whether there is multicollinearity among all these variables, the table 2 provide us the correlation matrix of all these variables. From table 2, there exist a clear multillinearity between GDP per capita , the total number of health professionals as well as the urban suburban population ratio and the Gini coefficient .By removing the multilinear variables and add new data as well as using panel data we can solve the problem of multilinearity in model B and model D. Because the multilinearity is in essence a phenomenon of sample, it is unnecessary for us to care about whether there exist multilinearity, but how serious the extent of multilinearity. Besides, the multilinearity will not become a serious problem if the only purpose of our analysis if to predict.

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Table 2 Correlation Coefficient

	RJGDP	V	D	W	UR	G
RJGDP	1					
V	0.9810	1				
D	0.9143	0.8900	1			
W	-0.5627	-0.6604	-0.5566	1		
UR	0.9429	0.9862	0.8327	-0.6985	1	
G	0.8665	0.9210	0.9210	-0.8371	0.9137	1

6. CONCLUSION

This paper uses the negative binomial counting data model to verify whether Smeed's law is applicable in our country. By applying the time series data we substantiate that there indeed exist an inverted U shape curve between the traffic accidents mortality and the economic growth which further illustrate that the Smeed's law is applicable in our country and this conclusion coincides with the result of some foreign researches. Some scholars such as Teik hua law(2009)， Ulf-G.Gerdtham(2002) are able to prove the relationship between the economic growth and traffic accidents mortality because they use the data from countries of different level of development so that the sample data is essentially more diversified. As they use the data from different countries, their research further took the political institution, legal environment, level of corruption of public sector into considerations. In this paper, as we use the data solely from mainland China and all the province is similar in its political as well as legal environment, therefore the influence of these socio-economic variables have already been removed.

We also introduce the number of autos, the level of medical treatment, the consumption of alcohol, the level of urbanization, the situation of income distribution and the road safety law and some other variables to analyze their impacts on the traffic accidents mortality. The result of our regression model indicates us that: the traffic accidents mortality tends to increase with the process of urbanization. Besides, the influence of the income distribution on traffic accidents mortality is not significant and this finding is differentiated with the discovery of some foreign researches. Although the mortality tends to increase with the development of economy, but with the improvement of the medical service of our country, the mortality of traffic accidents tend to decrease and this is one of the causes of the inverted U shape curve between economic growth and the traffic accidents mortality. Meanwhile, as the mortality of traffic accidents increase, people will keep on improving the safety condition of autos, using safer means of transportation and legislating relevant laws and all these self learning behavior will stimulate the formation of the inverted U shape curve.

Although by calculating time series models, the turning point has already been reached in China. However, as the time span of our research is pretty short, whether the number of mortality will rebound is still uncertain. As Chinese economy is developing at a very rapid speed, the number of cars will continue to increase; Moreover, as the process of urbanization in our country speed up, the road safety problem is still a very serious challenge. As a consequence, to prevent the number of people died in traffic accidents from rebounding, we should strengthen those measures that can prevent the traffic situation to deteriorate such as improving standard of medical service and legislating stricter laws.

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