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交通事故宏观计量经济学模型

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摘 要:从经济发展水平、人口数量、汽车保有量、道路情况等宏观因素入手,研究了国内外道路交通事故规律,分析了人均 GDP 与千人汽车保有量、万车死亡率、10 万人口死亡率之间的关系。以宏观计量经济学和柯布-道格拉斯函数为基础,利用 7 个国家的历史数据构建了交通事故面板数据模型。分别采用固定效应模型和随机效应模型进行参数估计,并进行了 Hausman 检验,得到 7 个国家的交通事故宏观计量经济学模型。计算结果表明:在交通事故参数中,10 万人口死亡率与人均 GDP、人均道路长度呈正相关,与千人汽车保有量呈负相关;通过 Hausman 检验,自由度为 3 的卡方分布值为 3.91,概率为 0.02,小于 0.05 的置信区间;与随机效应模型相比,固定效应模型各变量的置信区间都小于 0.05,拟合优度更好。可见,本文模型有效。

关键词:交通安全;事故模型;面板数据;宏观估计;固定效应;随机效应;Hausman 检验

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Macroscopic econometrics model of traffic accident

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Abstract: From the points of macroscopic factors such as economic development level, population number, vehicle ownership and road condition, the regularities of traffic accidents at home and abroad were analyzed. The relations among per capita GDP and vehicle ownership per 1 000 population, mortality per 10 000 vehicles, mortality per 100 000 population were studied. Based on macroscopic econometrics and Cobb-Douglas function, the panel data model of traffic accident was set up by using the historical data in seven countries. Fixed effect model and random effect model were used to estimate parameters respectively, Hausman test was carried out, and the macroscopic econometrics models of traffic accidents for the seven countries were set up. Calculation result shows that among the parameters of traffic accidents, mortality per 100 000 population is negative correlation with per capita GDP and per capita road length, mortality per 100 000 population is positive correlation with vehicle ownership per 1 000 population. Through Hausman test, chi-square distribution value is 3.91 when freedom is 3, the probability is 0.02 and less than the confidence level which is 0.05. Compared with the random effect model, all the confidence levels of variables for fixed effect model are less than 0.05, and the goodness of fit is better. So the fixed effect model is effective. 3 tabs, 6 figs, 18 refs.

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Key words: traffic safety; accident model; panel data; macroscopic estimation; fixed effect; random effect; Hausman test

0 Introduction

With the global economy continuous development, vehicle population is increasing. Traffic accident has become an important accident type because of the most death numbers and the biggest economic loss. According to historical data, in the past 30 years, traffic accident mortalities in the developing countries increase greatly, while traffic accident mortalities in the developed countries decrease in varying degrees. For instance, from 1980 to 2005, the mortality per 100 000 population of traffic accident increased by 3.4 times, the data in India increased by nearly 2 times, while the data in USA decreased by 34.5%, and the data in EU countries decreased by 20%-30%. Compared with the developed countries, per capita vehicle ownership in the developing countries is much lower, but the increase trend and absolute values of accident data such as mortality per 10 000 vehicles are higher. There is a great gap between the developing countries and the developed countries in economic development level and road condition. In addition, traffic accident mortality is also affected by relatively stable macroscopic factors such as national system.

At present, more attention is paid to microscopic road factors, the research of macroscopic factors is fewer, such as economic development level, population and vehicle ownership. Jia, et al analyzed the survey data of traffic accident, and got the nonlinear regreession model of traffic accident death numbers[1], the regression model only considers factors such as population and vehicle, with the increase of vehicle motorization level in the developed countries, the mortality per 100 000 population of traffic accident decreased, so the model is no longer suitable for the situation in the developed countries. Zhang, et al calculated the mortality per 10 000 vehicles and vehicle ownership in China from 1980 to 2002 by using the regression model, and found that there was a good fitting between calculation values and actual values[2]. But from 2003, the mortality numbers of traffic accidents decreased continuously in the next four years. Therefore, the model is also no longer suitable for the situation in China.

In 2001, Lassarre used macroscopic effects such as per capita GDP, the proportion of urban population and per capita road length to develop macroeconomics accident model for OECD countries[3]. But in the model, some indicators are only available in OECD countries, the application ability of the model is poor.

In 2003, Kopits, et al completed the World Bank Group's report named traffic and economic development, elaborated the relation between economic growth and traffic accident mortality. Based on Cobb-Douglas function, the model of traffic accident mortality and per capita GDP was set up, the regression analysis was divided into two modes, such as the mode of the developing countries and the mode of the developed countries. But the model only emphasizes the relation between per capita GDP and traffic accident mortality, the other effects such as road condition and vehicle population are not considered.

From the points of economic development level, vehicle ownership, population number, road condition, the regularities of traffic accidents at home and abroad are analyzed, the internal relation between traffic accident mortality and macroscopic effects can be found, and the macroscopic econometrics model can be set up by using the historical data in the seven countries.

1 Macroscopic law of traffic accident

Traffic accident mortality (F_0) is an interaction result of motorization level (F_2) and mortality per 10 000 vehicles (F_3). F_2 and F_3 are effected by economic development level, road condition, driving habit and other macroscopic factors, where economic development level has the largest impact on F_2 and F_3. The typical historical data from 1963 to 2009 in USA, China, Japan, France, UK, Italy and Brazil are analyzed, and the relations among F_0, F_2, F_3 and per capita GDP are explored[5-7].

1.1 Relation between per capita GDP and vehicle ownership per 1 000 population

The relations between per capita GDPs and vehicle ownerships per 1 000 population for seven countries are shown in Fig. 1, vehicle ownership and the elasticity cofficient of per capita GDP are shown in Fig. 2. From the points of development experiences in the developed countries, the vehicle demand always can be divided into four stages. In stage I, vehicle ownership increases slowly with the increase of income; in stage II, vehicle ownership increases rapidly with the increase of income; in stage III, vehicle ownership increases slowly, and is followed by a stable state; in stage IV, vehicle ownership no longer increases with the increase of income.

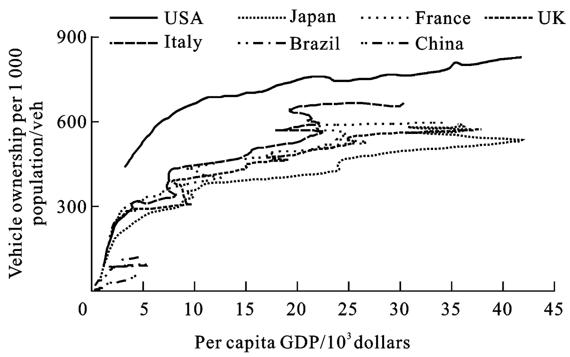

Fig. 1 Relations between per capita GDPs and vehicle ownerships per 1 000 population

In order to set up the quantitative relation between vehicle ownership and per capita GDP, the Gompertz function is used, regression equation is

$$V = \mu \exp(\omega e^{\sigma G}) \quad (1)$$

Where V is vehicle ownership per 1 000 population; G is per capita GDP; μ is saturation coefficient; ω and σ are negative parameters.

Through the regression analysis of historical data from 1963 to 2009 in China, the relation model between vehicle ownership per 1 000 population and per capita GDP is

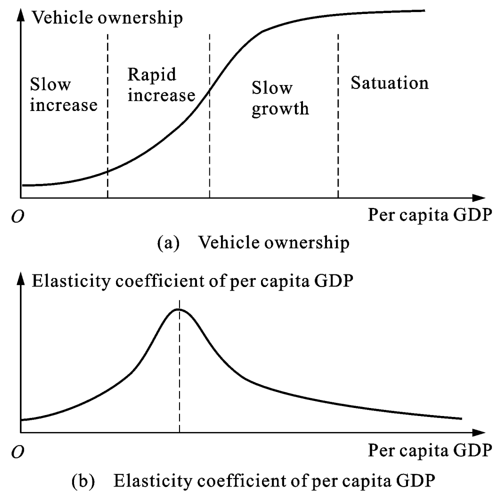

Fig. 2 Vehicle ownership and elasticity coefficient

$$V = 333\exp(-4.676\ 925\ 81e^{-0.000\ 036\ 83G}) \quad (2)$$

From the regression result, the inflexion point of elasticity coefficient for per captia GDP in China is 3 870 dollars. In 2010, the per capita GDP in China was about 4 382 dollars, vehicle ownership per 1 000 population in China was about 58 veh, it means that vehicle market in China has changed from stage II to stage III.

1.2 Relation between per capita GDP and mortality per 10 000 vehicles

The relations between per capita GDPs and mortalities per 10 000 vehicles in six countries are shown in Fig. 3. In the most countries, there is an inverse proportion relation between per capita GDP and mortality per 10 000 vehicles. With the increase of per capita GDP, vehicle ownership per 1 000 population becomes more and more, it makes government pay more attention to the improvement and advancement of traffic safety. The whole quality of population becomes higher, it also can play an important role on the improvement of traffic safety. Therefore, with the increase of per capita GDP, mortality per 10 000 vehicles has a downward trend.

Mortalities per 10 000 vehicles in USA, China, Japan, France, UK and Italy are shown in Fig. 4. Mortality per 10 000 vehicles in China is 3-5 times of that in the developed countries, and there is a big gap of per capita GDP between China and the developed countries. It shows that there is a

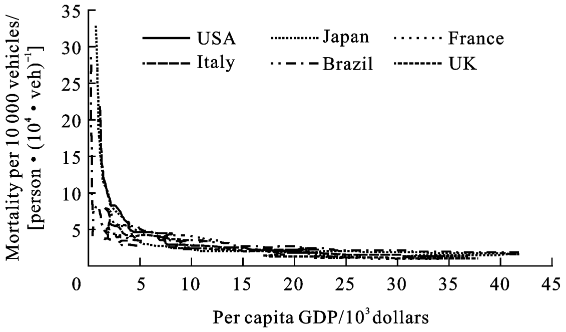

Fig. 3 Relations between per capita GDPs and mortalities per 10 000 vehicles

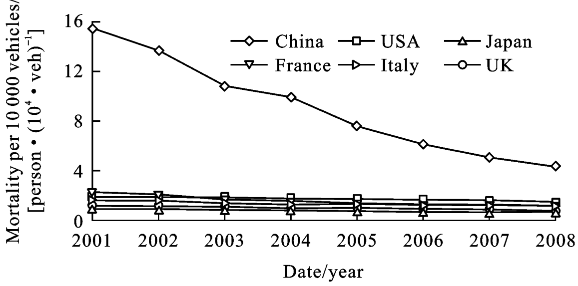

Fig. 4 Mortalities per 10 000 vehicles

negative correlation between per capita GDP and mortality per 10 000 vehicles in China.

1.3 Relation between per capita GDP and mortality per 100 000 population

The relations between per capita GDPs and mortalities per 100 000 population in the seven countries are shown in Fig. 5. In most countries, mortality per 100 000 population firstly increases and then decreases, and the inflection point of mortality per 100 000 population appears while the per capita GDP is in 2 000-5 000 dollars. In the early stages of development, with the increase of income, vehicles increase rapidly, and traffic accidents begin to deteriorate, the governments begin to adopt various measures to improve traffic status, so mortality per 100 000 population decreases.

2 Mocroscopic econometrics model

2.1 Model basic

The first important step in describing road traffic safety condition is to analyze the influence factors of traffic accident. Therefore, those factors chosen to develop models should be independent with each other, and various mathematical models must be compared during modeling process.

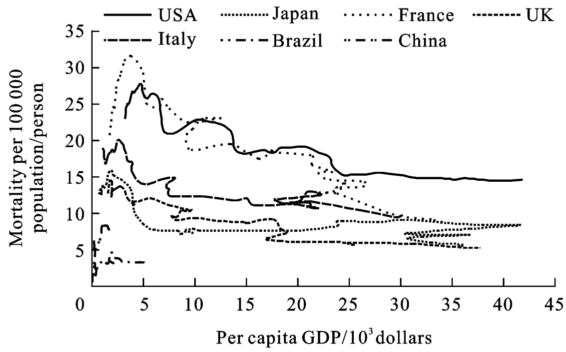

Fig. 5 Relations between per capita GDPs and mortalities per 100 000 population

Rules for selection factors affecting road traffic safety are as follows.

(1) It should be higher correlation between macroeconomics variables and dependent variables, and lower relevances among the macroeconomics variables.

(2) While the independent variables are chosen, it is possible to select variables with uniform unit to the independent variables, and use absolute value and percentage to avoid mathematical derivation.

(3) As a whole, time series model is better than segmentation model, because the segmentation model does not take geographical factor and cultural factor into account.

(4) Large data gaps may not be suitable for regression analysis.

(5) The selected variables are easy to access, as well as to guarantee reliability.

Several principles mentioned above are combined, four macroeconomics factors are chosen, mortolity per 100 000 population is chosen as dependent variable, per capita GDP, road condition and vehicle ownership per 1 000 population are chosen as indepentdent variables. In order to describe other factors, such as geography and culture, the surplus variable panel data model can be used.

2.2 Model construction

2.2.1 Panel data model

Up till now, macroeconomics data model is not widely used to describe accidents in China. It is common to adopt Cobb-Douglas function for regression analysis at abroad. Different macroeconomics variables are used to set up the model, the function equation form is[4-8]

$$F_{it} = \mathrm{e}^{\beta_0} \sum_{j=1}^{k} X_{jit}^{\beta_j} \mathrm{e}^{u_{it}} \quad (3)$$

Where F_{it} is mortality per 100 000 population; i is country series($i=1,2,\cdots,N$); t is year series($t=1,2,\cdots,T$); X_{jit} is the factor of F_{it}; u_{it} is surplus factor; k is the total number of factors; β_0, β_j are panel data coefficients.

Taking a logarithmic for Eq. (3)

$$\ln(F_{it}) = \beta_0 + \sum_{j=1}^{k} \beta_j \ln(X_{jit}) + u_{it} \quad (4)$$

2.2.2 Panel data model theory

Panel data model is known as two-dimensional data model including longitudinal section and cross section. From the cross section, multiple-entity at a certain moment constitutes section observations . From the longitudinal section, it is a time sequence[9]. Panel data is shown in Fig. 6.

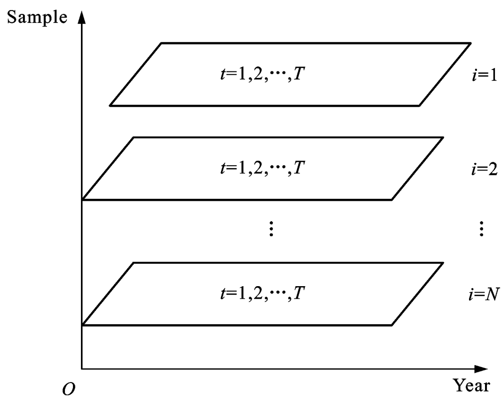

Fig. 6 Panel data

The form of panel data model is

$$y_{it} = a_i + X_{it}\beta + u_{it} \quad (5)$$

Where y_{it} is dependent variable; β is undetermined coefficient; a_i is individual effect.

There are two ways to deal with the individual effect. One is dependent variable which changes over time, the corresponding model can be called fixed effect model. The other is random effect, the model can be called random effect model. The fixed effect model reflects individual differences as particular intercept. The random effect model assumes that all individuals have the same intercept, and individual differences are mainly reflected in the set of random factors.

2.2.3 Hausman test

When panel data model is constructed, it is hard to make a choice between fixed effect model and random effect model. Therefore, it could make a choice between fixed effect model and random effects model by testing a_i.

Based on the Hausman test, the original hypothesis is that a_i is not related to other variables, OLS estimation from fixed effect model and GLS estimation from random effect model are unbiased and consistent. If the original hypothesis is not existed, the parameter estimation of fixed effect model keeps consistent, but the parameter estimation of random effect model is not suitable. Therefore, in the original hypothesis, parameter estimation should not be significant difference. Test equation is

$$W=\chi^2(k-1)=(\hat{L}-\hat{M})^{-1}\psi(\hat{L}-\hat{M}) \quad (6)$$

$$\psi(\hat{L}-\hat{M})=V(\hat{L})-V(\hat{M}) \quad (7)$$

Where W is the statistic value of Hausman test; $\chi^2(k-1)$ is the chi-square distribution while freedom is $k-1$; $\hat{L}$ is the OLS estimation of fixed effect model; $\hat{M}$ is the GLS estimation of random effect model; $V(\cdot)$ is variance function.

3 Calculation result analysis

The historical data of mortalities per 100 000 population, per capital GDPs, per capita road lengths from 1963 to 2009 in USA, China, Japan, France, UK, Italy and Brazil are used in regression analysis[10-13].

According to references [14-18], the macroscopic econometrics model of road traffic accident is

$$\ln(F_{it}) = a + b\ln(G_{it}) + c\ln(R_{it}) + d\ln(V_{it}) + u_{it} \quad (8)$$

Where R_{it} is per capita road length; b, c, d are regression coefficients; a, G_{it}, V_{it} correspond to a_i, G, V.

Regression results are shown in Tabs. 1-3, in Tabs. 1-3, R, u correspond to R_{it}, u_{it}.

From the Hausman test, W is 3.91. While p value is bigger than W, the probability is 0.02, it is appropriate to use fixed effect model to describe the relation between traffic accident and economic effects.

Tab. 1 Regression result of fixed effect model

Parameters	$\hat{L}$	t test value	p value
ln(G)	−0.644 60	−25.68	0.000
ln(R)	−0.293 15	−3.28	0.027
ln(V)	1.035 67	24.69	0.000
a	0.977 37	1.95	0.000
u	0.476 64		

Tab. 2 Regression result of random effect model

Parameters	$\hat{M}$	t test value	p value
ln(G)	−0.642 87	−25.69	0.000
ln(R)	−0.302 62	−3.57	0.001
ln(V)	1.033 13	24.85	0.000
a	0.919 29	24.85	0.072
u	0.471 88		

Tab. 3 Hausman test

Parameters	$\hat{L}$	$\hat{M}$	$\hat{L}-\hat{M}$
ln(G)	−0.644 60	−0.642 87	−0.001 73
ln(R)	−0.293 15	−0.302 63	0.009 48
ln(V)	1.035 67	1.033 13	0.002 54

Therefore, the formula of fixed effect model is

$$\ln(F_{it})=0.977\,37-0.644\,60\ln(G_{it})-0.293\,15\ln(R_{it})+1.035\,67\ln(V_{it})+u_{it} \tag{9}$$

Taking a logarithm for Eq. (9)

$$F_{it}=\mathrm{e}^{0.977\,37}G_{it}^{-0.644\,60}R_{it}^{-0.293\,15}V_{it}^{1.035\,67}\mathrm{e}^{u_{it}} \tag{10}$$

At the same time, using each national intercept, the traffic macroscopic accident econometrics models of USA, China, Japan, France, UK, Italy and Brazil respectively are

$$\begin{cases} F_{1t}=\mathrm{e}^{1.281\,773}G_{1t}^{-0.644\,60}R_{1t}^{-0.293\,15}V_{1t}^{1.035\,67} \\ F_{2t}=\mathrm{e}^{1.491\,024}G_{2t}^{-0.644\,60}R_{2t}^{-0.293\,15}V_{2t}^{1.035\,67} \\ F_{3t}=\mathrm{e}^{0.744\,632\,8}G_{3t}^{-0.644\,60}R_{3t}^{-0.293\,15}V_{3t}^{1.035\,67} \\ F_{4t}=\mathrm{e}^{1.390\,349}G_{4t}^{-0.644\,60}R_{4t}^{-0.293\,15}V_{4t}^{1.035\,67} \\ F_{5t}=\mathrm{e}^{0.532\,802\,5}G_{5t}^{-0.644\,60}R_{5t}^{-0.293\,15}V_{5t}^{1.035\,67} \\ F_{6t}=\mathrm{e}^{0.738\,067\,9}G_{6t}^{-0.644\,60}R_{6t}^{-0.293\,15}V_{6t}^{1.035\,67} \\ F_{7t}=\mathrm{e}^{0.256\,435\,5}G_{7t}^{-0.644\,60}R_{7t}^{-0.293\,15}V_{7t}^{1.035\,67} \end{cases} \tag{11}$$

From the above analysis, the results are as follows.

(1) The confidence levels of ln(G), ln(R), ln(V) and a are less than 0.05, the value of F test is 157.75, so the regression effect and the degree of fit are good.

(2) Mortality per 100 000 population, per capita GDP, per capita road length and vehicle ownership per 1 000 population all exceed 0.05, it shows that independent variables and dependent variables are positive correlation.

(3) Due to the increase of GDP and the improvements of population quality, investment and related policy support, per capita GDP is negative correlation with traffic accident. Per capita road length is negative correlation with traffic accident mortality. The higher the motorization level is, the higher the chance of traffic accident is. In the most developed countries, the traffic accident mortality firstly increases and then decreases, but in China, the inflexion point of traffic accident mortality is not obvious, so the traffic accident mortality is still to increase if the vehicle ownership per 1 000 population increases rapidly.

(4) There are large differences among individual fixed effects, so the development trends between the developing and the developed countries are different.

4 Conclusions

Mortality per 100 000 population, per capita GDP, vehicle ownership per 1 000 population are analyzed, the relation between motorization level and traffic accident is analyzed. Fixed effect model and random effect model are used. Hausman test result shows that the fixed effect model is more suitable for the description of relation. According to regression results, Chinese government should pay more attention to traffic safety in the future.

References:

[1] JIA Shou-zhen, LI Zhao-peng, CHEN Si-yuan, et al. The applicability discussion of the Smeed model[J]. Journal of Xi'an Highway University, 1998, 18(3): 276-279.

[2] ZHANG Wei-hua, LU Hua-pu. Analysis of vehicle delay of intersections with per-signals based on bus priority[J]. China Journal of Highway and Transport, 2005, 18(4): 78-82.

[3] LASSARRE S. Analysis of progress in road safety in ten European countries[J]. Accident Analysis and Prevention, 2001, 33(6): 743-751.

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SHAO Jun-gang, XU Xiao-bing, WANG Yu, et al. Handling capacity of operation phase in Yangshan Port Area[J]. Journal of Shanghai Maritime University, 2008, 29(4): 25-28. (in Chinese)

[12] 马 勇. 基于排队论的T型航路船舶交通通过能力研究[D]. 大连:大连海事大学,2008.
MA Yong. Research on vessel traffic pass through capacity of T-type channel based on queuing theory[D]. Dalian: Dalian Maritime University, 2008. (in Chinese)

[13] 刘敬贤,韩晓宝,易湘平. 基于排队论的受限航道通过能力计算[J]. 中国航海,2008,31(3):261-268.
LIU Jing-xian, HAN Xiao-bao, YI Xiang-ping. Capacity analysis of restricted channels based on the queuing theory[J]. Navigation of China, 2008, 31(3): 261-268. (in Chinese)

[14] SHABAYEK A A, YEUNG W W. A simulation model for the Kwai Chung container terminals in Hong Kong[J]. European Journal of Operational Research, 2002, 140(1): 1-11.

[15] 刘敬贤,李昌伟,刘 文. 基于排队论的锚地规模论证分析[J]. 船海工程,2009,38(4):158-161.
LIU Jing-xian, LI Chang-wei, LIU Wen. Anchoring zone scale analyzes based on the queuing theory[J]. Ship and Ocean Engineering, 2009, 38(4): 158-161. (in Chinese)

[16] SINGER M, DONOSO P. Assessing an ambulance service with queuing theory [J]. Computers amd Operations Research, 2008, 35(8): 2549-2560

[17] 赵景丽. 基于排队论的沿海港口航道通过能力及服务水平研究[D]. 青岛:中国海洋大学,2010.
ZHAO Jing-li. Research on channel transit capacity and service level of sea port based on queuing theory[D]. Qingdao: Ocean University of China, 2010. (in Chinese)

[18] 计明军,陈 哲,王清斌. 集装箱船舶支线运输航线优化算法[J]. 交通运输工程学报,2011,11(4):68-75.
JI Ming-jun, CHEN Zhe, WANG Qing-bin. Optimization algorithm of branch transportation route for container ship[J]. Journal of Traffic and Transportation Engineering, 2011, 11(4): 68-75. (in Chinese)

[19] 郑士源. 干散货运输船舶投资订购的内在影响机制[J]. 交通运输工程学报,2012,12(1):87-94.
ZHENG Shi-yuan. Intrinsic influence machanisms of dry bulk ship investment and ordering [J]. Journal of Traffic and Transportation Engineering, 2012, 12(1): 87-94. (in Chinese)

(上接第75页)

[4] KOPITS E, CROPPER M. Traffic fatalities and economic growth[R]. Washington DC: World Bank Group, 2003.

[5] AN Wu-mei. Macroscopical analysis and modeling in traffic safety[D]. Beijing: Beijing University of Technology, 2002.

[6] YE Xing-cheng. A systemic research on the road safety[D]. Wuhan: Wuhan University of Technology, 2005.

[7] LIU Yun-tong. A fuzzy-based model for macroscopic evaluation of road traffic safety[J]. China Journal of Highway and Transport, 1995, 8(S1): 169-175.

[8] PAGE Y. A statistical model to compare road mortality in OECD countries [J]. Accident Analysis and Prevention, 2001, 33(3): 371-385.

[9] XU Ting, SUN Xiao-duan, WANG Wei-li, et al. Highway accidents statistical analysis with panel data model[J]. Journal of Beijing University of Technology, 2010, 36(4): 495-499.

[10] State Statistical Bureau. China Statistical Yearbook in 2010[M]. Beijing: China Statistics Press, 2010.

[11] International Road Federation. World road statistics[D]. Washington DC: International Road Federation, 2009.

[12] Japan Automobile Manufacturers Association. World motor vehicle statistics in 2010 [R]. Tokyo: Japan Automobile Manufacturers Association, 2011.

[13] World Bank Group. World development indicators[R]. Washington DC: World Bank Group, 2009.

[14] PAULOZZI L J, RYAN G W, ESPITIA-HARDEMAN V E, et al. Economic development's effect on road transport-related mortality among different types of road users: a cross-sectional international study[J]. Accident Analysis and Prevention, 2007, 39(3): 606-617.

[15] SCUFFHAM P A, LANGLEY J D. A model of traffic crashes in New Zealand[J]. Accident Analysis and Prevention, 2002, 34(5): 673-687.

[16] LI Ju-ping. Mechanism improvement for road traffic accidents indentification[J]. Journal of Chang'an University: Social Science Edition, 2009, 11(3): 26-29, 35.

[17] QIAO Xiang-ming, XU An, SHU Wei. Developing tendency forecast of road traffic accident in China[J]. Journal of Chang'an University: Natural Science Edition, 2004, 24(6): 64-66.

[18] YANG Shao-wei, WANG Hai-jun, ZHANG Chi, et al. Reation between possible speed and traffic accidenct[J]. Journal of Chang'an University: Natural Science Edition, 2009, 29(4): 34-38.