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ROAD SAFETY DEVELOPMENT AND ECONOMIC GROWTH IN CHINA FROM 1979 TO 2018

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Abstract. Road safety development is affected by both motorization rates and economic growth. This phenomenon is studied using the Kuznets curve model, which uses data such as the number of road fatalities, the population, the number of vehicles, and the gross domestic product (GDP) per capita, all of which are verified by applying the data envelopment analysis (DEA) model. The results showed that there were strong links between road safety development and economic growth in China. As GDP per capita rose from 1979 to 2018, the number of vehicles per person increased and the number of fatalities per vehicle decreased, producing a relationship that followed an N-shaped curve. However, in 2002, the relationship between the road mortality rate and GDP per capita followed an inverted U-shaped curve; the point at which this happened in the Kuznets curve was the turning point for road safety performance in China. Thus, road mortality rates increased as GDP per capita increased, but declined once GDP per capita exceeded 17 187 CNY. The analysis that stems from the results of the Kuznets curve model is consistent with the performance evaluation derived from the DEA-based road safety model. The findings could provide an important reference for policymakers to improve road safety under harsh economic conditions.

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Keywords: data envelopment analysis, Kuznets curve, road safety, safety performance, safety management, safety development.

Introduction

Road traffic accidents have been recognised as a significant public health issue since they cause heavy casualties and great economic losses (Kreicbergs et al., 2021). Most of the world's road fatalities occur in developing or transitional countries (Gutierrez-Osorio & Pedraza, 2020). The economic cost of road traffic accidents has been calculated to cost approximately 5% of the gross domestic product (GDP) in lower and middle-income countries (Litman, 2018).

Rapid economic development has been accompanied by an exponential increase in the level of motorization, which is creating challenges for road safety (Kang et al., 2021). Many scholars found that economic factors had an impact on road traffic accidents and fatalities. For instance, Söderlund & Zwi (1995) found that road traffic fatalities increased when income was low but fell when income was higher. Law et al. (2011) found that the Kuznets curve showed a relationship between per capita income and the number of road fatalities for developed and developing countries. Al-Reesi et al. (2013) found that economic growth was associated with an increase in motorization rates, with an increased motorization rate having a direct relationship with the number of road fatalities. Nishitateno & Burke (2014) found a motorcycle Kuznets curve that saw motorcycle dependence increase and then decrease as economies grew. Yannis et al. (2014) analysed the relationship between road mortality rates and GDP per capita for 27 European countries from 1975 to 2011, which revealed that an annual increase of GDP per capita led to an annual increase in the road mortality rate and an annual decrease of GDP per capita led to an annual decrease in the road mortality rate. Chen (2014) investigated the association between road mortality rates and economic development to uncover that an increase of, on average, 1% in economic growth was associated with a 1.1% increase in the road mortality rate. He et al. (2015) found that road fatalities decreased monotonically with economic growth in most Russian federal regions from 2004 to 2011. Lloyd et al. (2015) found that the economic recession in Britain changed behaviours, which resulted in a reduction in the number of road fatalities from 2007 to 2010. Through analysing state-level data in the US from 1984 to 2014, Noland & Zhou (2017) found that a decline in economic activity lowered the number of road traffic fatalities. Castillo-Manzano et al. (2020) corroborated the Kuznets curve hypothesis for road traffic accidents in the long term through an econometric analysis of the impact of the support program on road safety performance. These studies revealed that there was a link between road mortality rates and economic development. However, due to the different conditions and legal systems of each country and region, there are some disparities in the reasoning behind road safety development.

China is the largest developing country and has maintained rapid long-term economic growth since its reform and opening up. China's GDP per capita in 2018 was 22.8 times that of its GDP per capita in 1979 (based on 2018 prices), according to the National Bureau of Statistics of China. Economic growth affects road safety since it increases the level of vehicle ownership and the level of traffic. The National Bureau of Statistics in China reported that the number of road fatalities in China saw a dramatic increase and then underwent a dramatic decrease. Some studies indicated that the relationship between income growth and road fatalities was similar to the Kuznets curve, which was parallel to the one that existed for the relationship between income inequality and per capita income for many countries and regions (Anbarci et al., 2009; Law et al., 2011). However, fewer studies examined the hypothesis that the change in the amount of road mortalities was correlated with the level of economic development in China. Therefore, this provides us with an opportunity to use the Kuznets curve model for analysing the relationship between road mortality rates and economic growth in China. Moreover, data envelopment analysis (DEA) was applied in many studies to measure road safety performance (Mozaffari et al., 2021; Kang & Wu, 2022), for instance, in a study that evaluated Chinese provincial road safety performance from 2007 to 2016 (Kang & Wu, 2021) and in another that analysed the road safety performance of EU-23 countries from 2005 to 2014 (Nikolaou & Dimitriou, 2018). DEA can therefore be used to test the feasibility of the Kuznets curve model to understand road safety development in China.

This study examines how road fatality rates changed as per capita income grew from 1979 to 2018. To identify the relationship between road mortality rates and economic growth, we will examine how an increase in levels of income correlates with the improvement in road safety. This study will help policymakers implement effective road safety measures to reduce the risk of road traffic fatalities in times of limited economic growth.

1. Methods

1.1. The Kuznets curve model

According to some studies, the Kuznets curve model can be used to analyse the relationship between road mortality rates and economic growth (McManus, 2007; Law et al., 2011; Castillo-Manzano et al., 2020). We can assume that Chinese economic development – measured by GDP per capita – is a proxy for all factors affecting the rate of road fatalities.

The road mortality rate, that is, the number of road traffic fatalities per population, is the product of the number of vehicles per person and the number of fatalities per vehicle. The road fatality rate depends on the rate of growth in motorization and the rate of change in the number of fatalities per vehicle. From 1979 to 2018, vehicle ownership in China grew 148.4-fold and the number of vehicles per person grew 103.4-fold, which was at a faster rate than the number of fatalities per vehicle fell, which was by 50.7-fold. Meanwhile, GDP per capita grew 22.8-fold – based on 2018 prices – according to the National Bureau of Statistics of China.

The relationship between the number of fatalities per population (F/P), the number of vehicles per population (V/P), the number of fatalities per vehicle (F/V), and GDP per capita can be understood through statistical models that follow the general form:

$$\text{Linear model: } z = c(0) + c(1) \cdot y + \varepsilon, \tag{1}$$

$$\text{Quadratic model: } z = c(0) + c(1) \cdot y + c(2) \cdot y^2 + \varepsilon, \tag{2}$$

$$\text{Cubic model: } z = c(0) + c(1) \cdot y + c(2) \cdot y^2 + c(3) \cdot y^3 + \varepsilon, \tag{3}$$

where z refers to F/P, V/P, and F/V, respectively; y refers to GDP per capita (based on 2018 prices); $c(t)$ denotes the undetermined coefficient ($t = 0, 1, 2, 3$), reflecting the changing relationship between the road fatality rate and economic growth; and ε denotes a random disturbance term.

- When $c(1) = c(2) = c(3) = 0$, there is no correlation between z and y.
- When $c(1) \neq 0$, $c(2) = c(3) = 0$, the relationship between z and y is linear.
- When $c(1) > 0$, $c(2) < 0$, $c(3) = 0$, the relationship between z and y follows an inverted U-shaped curve.
- When $c(1) < 0$, $c(2) > 0$, $c(3) = 0$, the relationship between z and y follows a U-shaped curve.
- When $c(1) > 0$, $c(2) < 0$, $c(3) > 0$, the relationship between z and y follows an N-shaped curve.
- When $c(1) < 0$, $c(2) > 0$, $c(3) < 0$, the relationship between z and y follows an inverted N-shaped curve.

1.2. DEA-based road safety model

DEA is designed to handle multiple input and output parameters and has been identified as a suitable tool for assessing the performance of a set of decision-making units (DMUs). The DEA method has been used for evaluating the safety performance of various forms of transport infrastructure (Kang & Wu, 2022), such as runways, railway level crossings, and roads. The DEA-based road safety model is applied to choose the best possible input and output weights under the imposed restrictions to maximize the performance score, that is, the outputs need to be as low as possible for the same inputs. The scoring for road safety performance ranges from 0 to 1, with a higher score being indicative of a better road safety performance. Input variables consist of the population, the number of vehicles, and the GDP per capita, while the output gives the number of fatalities. The system of equations for measuring the safety performance score (SPS) as a function of road traffic accidents can be described as follows:

$$\text{SPS} = \min \theta, \tag{4}$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^{n} \lambda_j x_{ij} \geq x_{i0}, \ i=1,2,\ldots,m \\ \sum_{j=1}^{n} \lambda_j y_{rj} \leq \theta y_{r0}, \ r=1,2,\ldots,s, \\ \lambda_j \geq 0, \ j=1,2,\ldots,n \end{cases} \tag{5}$$

where λ_j refers to the weight produced by DMU_j, which is a member of the set $j = 1, 2,\ldots,n$; x_{ij} and y_{rj} refer to the known ith input and rth output respectively produced by DMU_j; x_{i0} and y_{r0} refer to the known ith input and rth output respectively produced by DMU_0 (the DMU under evaluation); and θ refers to the measure of efficiency for DMU_0.

1.3. Data collection and description

The data concerning the number of fatalities (F), the population (P), the number of vehicles (V), and the GDP per capita (Y) between 1979 and 2018 were collated from the *China Statistical Yearbook (1999-2019)*, the *Compilation of 50-Year (1949-1999) Statistics of China's Industrial Transportation Energy*, and the *China Transportation Yearbook (1986-2018)*.

Based on the T-statistic, the probabilities of F/P, V/P, and Y are greater than 10% and only the probability of F/V is less than 5% (see Table 1). To eliminate non-stationary data, we used logarithmic variables

Table 1. Results of the augmented Dickey-Fuller test

Description	ln(*F/P*)	*F/V*	Δln(*V/P*)	Δln*Y*
T-statistic	−1.6836	−3.5782	−2.8074	−4.5110
1% level	−2.6272	−4.2191	−3.6156	−3.6210
5% level	−1.9499	−3.5331	−2.9411	−2.9434
10% level	−1.6115	−3.1983	−2.6091	−2.6103
P-value	0.0869	0.0453	0.0667	0.0009
Results	Significant	Significant	Significant	Significant

Note: *Y* is measured based on 2018 prices. *F/P*, *F/V*, and *V/P* are calculated by fatalities/10 000 persons, fatalities/10 000 vehicles, and vehicles/10 000 persons, respectively.

such as *F/P*, *V/P*, and *Y*. After adopting the natural logarithm for the three variables, the probability of ln(*F/P*) was less than 10%. Also, the first difference of ln(*V/P*) and that of ln*Y* were less than 10% and 1%, respectively.

2. Results and discussion

2.1. Motorization and GDP per capita

Regression analyses of the number of vehicles per person and GDP per capita in China from 1979 to 2018 were conducted. The polynomial models (as represented by Equations (1) to (3)) were used for fitting and the model with the best fitting degree was selected as the first choice. Table 2 shows that the value of R^2 for the cubic function is greater than 0.999 and the degree of correlation for the cubic model is significant. The equation of the fitting curve between *V/P* and *Y* is described as follows:

$$\ln(V/P) = -73.60707 + 23.77448 \cdot \ln Y - 2.531803 \cdot (\ln Y)^2 + + 0.094469 \cdot (\ln Y)^3. \quad (6)$$

From Figure 1, we can see that the relationship between the number of vehicles per person and GDP per capita in China between 1979 and 2018 follows the Kuznets curve, that is, the relationship between ln(*V/P*) and ln*Y* follows an N-shaped curve. As GDP per capita rose from 1979 to 2018, the number of vehicles per person also increased.

Over the past four decades, the Chinese automotive industry has developed rapidly. In 1979, when the national population totalled around 975.42 million, automobile manufacturing experienced low productivity and total vehicle output only amounted to around 0.186 million. Household demand for cars grew rapidly as per capita income grew, which resulted in many cars being imported to China. High tariffs were implemented to protect the fledgling Chinese automotive industry (Li et al., 2015). In the mid-1990s, the automotive industry was designated as one of the pillars of the Chinese economy (Chen, 2018). To increase their production capacity and enhance their technical manufacturing

Table 2. The fitting results between ln(*V*/*P*) and ln*Y*

Item	Linear model	Quadratic model	Cubic model
c(0)	–8.479760[a]	5.545503[a]	–73.60707[a]
c(1)	1.408939[a]	–1.571670[a]	23.77448[a]
c(2)	-	0.156687[a]	–2.531803[a]
c(3)	-	-	0.094469[a]
R^2	0.988491	0.997225	0.999252
Adjust R^2	0.988188	0.997075	0.999190
Durbin-Watson	0.066515	0.185802	0.597537
Relationship	linear	U-shaped	N-shaped

Note: a refers to the significance under the conditions of 1%.

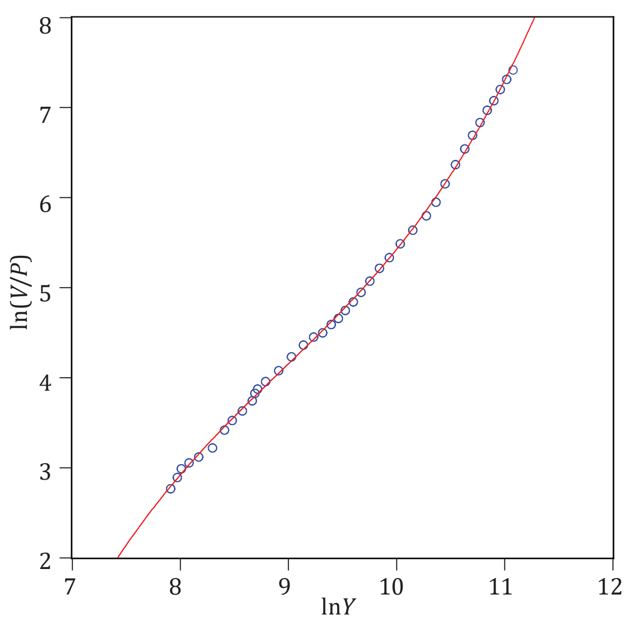

Figure 1. The correlation between the number of vehicles per person and GDP per capita from 1979 to 2018

capabilities of passenger vehicles, some large state-owned automobile enterprises partnered with foreign automobile manufacturers to form joint ventures and foreign ownership was capped at 50% to protect Chinese manufacturers. Through these commercial arrangements, a large number of talented people have been trained, which has fostered the development of the Chinese automotive industry. Private automobile enterprises have developed significantly, which has improved the Chinese automotive industry's performance in global markets. China entered the World Trade Organization in 2001. Since then tariffs on foreign automobiles have reduced; for example, within the five years, tariffs have been cut from 100% to 25%. The automobile production capacity of Chinese enterprises and Chinese-foreign joint ventures has substantially grown; the number of automobiles manufactured increased from 2.34 million to 29.02 million between 2001 and 2017, meaning that vehicle output increased by 11.4-fold. Since 2009, the Chinese automobile market has become the largest in the world, having surpassed the American automobile market both in terms of sales and production capacity (Chen et al., 2020). The annual gross domestic product of the Chinese automotive industry has exceeded 5% of its annual GDP since 2002 and constituted as high as 9.26% of its GDP in 2018.

China's share of global GDP grew from 1.7% in 1978 to 15.8% in 2018 (Wang et al., 2021). Due to this rapid economic development, China's transport network has also grown rapidly. For example, the National Bureau of Statistics of China reported that the length of highways totalled 1 698 000 km in 2001 and increased to 4 846 500 km in 2018, meaning the total length increased 1.85-fold. With the rapid development of the economy and the improvement in people's living standards, the motorization rate has increased significantly. The total number of vehicles owned in China increased from 1 554 900 to 232 312 300 during the past four decades, constituting a growth rate of 14 841%. However, the rate of car ownership per capita in China is still relatively low. In 2018, there were approximately 166.49 cars per thousand people, which was far lower than the average rate in developed countries. However, motorization rates will continue to increase as purchasing power grows.

2.2. The number of fatalities per vehicle and GDP per capita

Regression analyses of the number of fatalities per vehicle and GDP per capita in China from 1979 to 2018 were conducted by using polynomial models (as represented by Equations (1) to (3)). Table 3 shows that the value of R^2 for the cubic function is higher than 0.95 and the degree of correlation for the cubic model is significant. The equation for the fitting curve between F/V and Y is described as follows:

$$F/V = -5717.767 + 1946.746 \cdot \ln Y - 211.8721 \cdot (\ln Y)^2 + 7.469946 \cdot (\ln Y)^3. \quad (7)$$

From Figure 2, we can see that the relationship between the number of fatalities per vehicle and GDP per capita in China between 1979 and 2018 follows the Kuznets curve, that is, the relationship between F/V

Table 3. The fitting results between F/V and ln$Y$

Item	Linear model	Quadratic model	Cubic model
c(0)	477.0188[a]	541.0927[a]	–5717.767[a]
c(1)	–43.84224[a]	–57.45903	1946.746[a]
c(2)	–	0.715817	–211.8721[a]
c(3)	–	–	7.469946[a]
R^2	0.937984	0.938162	0.950585
Adjust R^2	0.936352	0.934820	0.946467
Durbin-Watson	0.509719	0.511725	0.634089
Relationship	linear	U-shaped	N-shaped

Note: a refers to the significance under the conditions of 1%.

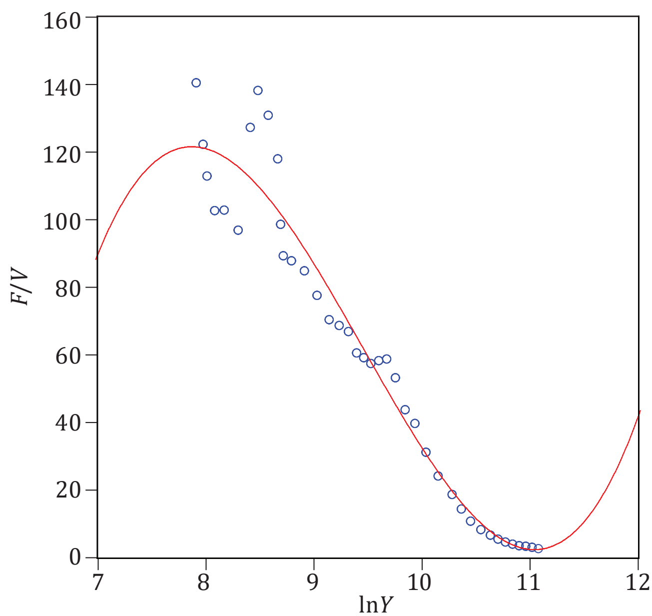

Figure 2. The correlation between the number of fatalities per vehicle and GDP per capita from 1979 to 2018

and ln$Y$ follows an N-shaped curve. As GDP per capita rises from 1979 to 2018, the number of fatalities per vehicle decreases. These results are consistent with the findings of Page (2001), who also revealed that the number of road fatalities per vehicle decreased over time as GDP per capita increased.

Although the vehicle ownership rate in China increased each year, the number of road fatalities dropped dramatically from 2004 to 2015, which was frequently attributed to the significant developments and investments made in transportation infrastructure (Jiang et al., 2017). Furthermore, the Chinese government has invested greatly in the public transport system to improve traffic congestion in cities (Liu & Li, 2020) and to encourage people to use public transport, such as the subway and bus. These measures can also decrease the amount of exposure to traffic that involves risks for the entire population and will also help reduce road traffic accidents and casualties. It is noteworthy that there was a fluctuation in the number of road traffic accidents in the last five years. This situation requires policymakers to carry out safety countermeasures. In addition, the fitting N-shaped curve has shown an upward trend since 2018 as GDP per capita has risen, which can be reversed if effective safety countermeasures are implemented.

2.3. Road mortality and GDP per capita

Regression analyses of road mortality rates and GDP per capita in China from 1979 to 2018 were conducted by using polynomial models (as represented by Equations (1) to (3)). Table 4 shows that the value of R^2 for the quadratic function is higher than 0.89 and the degree of correlation for the quadratic model is significant. The equation of the fitting curve between F/P and Y is described as follows:

$$\ln(F/P) = -35.34469 + 7.161820 \cdot \ln Y - 0.366530 \cdot (\ln Y)^2. \quad (8)$$

From Figure 3, we can see that the relationship between the road mortality rate and GDP per capita in China from 1979 to 2018 follows the Kuznets curve, that is, the relationship between ln(F/P) and ln$Y$ follows an inverted U-shaped curve. While GDP per capita increased from 1979 to 2018, the number of road mortalities increased from 1979 to 2002 but then decreased from 2002 to 2018.

The turning point in the fitting inverted U-shaped curve occurred in 2002. GDP per capita in China was 17 187 CNY (based on 2018 prices) in 2002, meaning that road mortalities in China increased as GDP per capita increased but declined once GDP per capita exceeded 17 187 CNY – the equivalent of around 2569 US dollars. These findings correlate with the conventional view, that is, that from the period where GDP per capita increased from 1000 to 3000 US dollars, road traffic accidents were frequent. This is largely due to the fact that, when income is low, societies are less able to devote resources to establishing road safety institutions that will formulate and implement road safety policies. When GDP per capita reached above 3000 dollars, road safety conditions improved. This is primarily because societies have an ability to invest

Table 4. The fitting results between ln(*F*/*P*) and ln*Y*

Item	Linear model	Quadratic model	Cubic model
c(0)	–2.536059[a]	–35.34469[a]	–49.18148[c]
c(1)	0.189424[a]	7.161820[a]	11.59262
c(2)	-	–0.366530[a]	–0.836509
c(3)	-	-	0.016514
R^2	0.243329	0.894247	0.895091
Adjust R^2	0.223416	0.888530	0.886348
Durbin-Watson	0.088978	0.467718	0.470312
Relationship	linear	inverted-U-shaped	N-shaped

Note: a and c refer to the significance under the conditions of 1% and 10%, respectively.

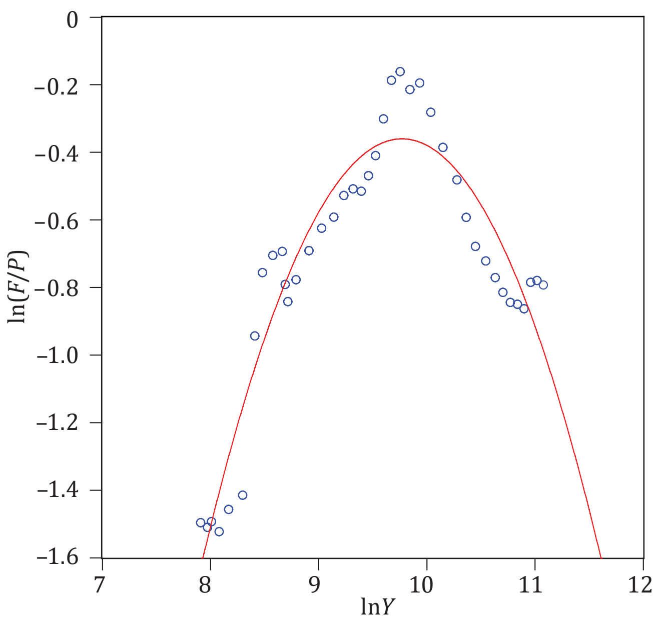

Figure 3. The correlation between the number of road mortalities and GDP per capita from 1979 to 2018

more resources in road safety when income is high and people are more concerned about road safety.

As per capita income rises, shifting from high-risk, non-motorized transport to lower risk, motorized transport would be beneficial to reduce the number of overall road fatalities (Söderlund & Zwi, 1995; Law et al., 2011). With increasing motorization, pedestrians, who are a low threat but are at a higher risk, will be replaced with vehicles that pose a higher threat but are at a lower risk. With the increase in the rate of car ownership, the number of Chinese drivers grew dramatically from 1978 to 2018. For instance, there were 1.92 million drivers in 1978, 37.47 million in 2000, and 369.23 million drivers in 2018. With the rapid development of express delivery and bike-sharing services, cyclists and riders still account for the largest proportion of road users. Pedestrians, cyclists, and riders are regarded as vulnerable road users (Wong et al., 2002) who accounted for more than 70% of road fatalities in China (Wang et al., 2019b). Vulnerable road users are key targets where countermeasures have the most potential to substantially decrease the number of road fatalities (Zhang et al., 2010).

Road safety laws are very important for saving valuable human lives (Ali et al., 2019). The Chinese government issued and implemented the Road Traffic Safety Law of the People's Republic of China in October 2003 and May 2004, respectively. This law defines the responsibilities and obligations that are required to maintain road safety from the perspective of drivers, which includes road traffic conditions, road traffic regulations, traffic accident handling, law enforcement and supervision, and legal responsibility. Thereafter, Chinese road fatalities have been declining owing to the improvement and expansion of road traffic infrastructure (Wang et al., 2019a). Road fatalities caused by drink-driving in China accounts for between 18.45% and 25.26% (Wang et al., 2015b). The implementation of stricter drink-driving laws in April 2011 became the first time that driving under the influence of alcohol became criminalized and that penalties were increased for driving under the influence (Fei et al., 2020). The Chinese government also launched the Civilization Traffic Action Plan in 2010 to raise public awareness regarding road safety. These measures produced notable results, including a significant reduction in road fatalities. In addition, factors such as economic development and population density have impacted road traffic management policies; for instance, since 2009, the Chinese government has prohibited motorcycles in most large and medium-sized cities but has continued to allow them in rural areas.

Investments in health and transportation have a significant impact on the number of road traffic accidents and fatalities (Sun et al., 2019). For instance, spending on health amounted to 83.23 billion CNY and 1306.76 billion CNY in 2004 and 2016, respectively, meaning it increased 14.7-fold. This has brought significant improvements in rescue operations, which has enabled those injured in road traffic accidents to receive timely medical treatment. The number of health institutions in China rose from 291 320 in 2004 to 997 430 in 2018, constituting an increase of 242.38%. This demonstrates that health care in China is constantly improving, which will help decrease the road fatality rate. The investments made in the field of transportation totalled 24.48 billion CNY and 968.66 billion CNY in 2004 and 2016, respectively, constituting a 38.6-fold increase and a cumulative investment of 6508.60 billion CNY, which reflected greater importance that the Chinese government attributed to road safety management and construction.

2.4. Road safety performance

DEA is a common method for policymakers to compare road safety performance in China, which can help us further corroborate the relationship between the road mortality rate and GDP per capita. The performance score of Chinese road safety was computed by using the DEA-based road safety model (as represented by Equations (4) to (5)). The higher the score, the better the road safety performance. From Figure 4, we can see that, while the Chinese economy continued to grow throughout the period between 1979 and 2018, the performance of road safety deteriorated from 1979 to 2002 and then improved from 2002 to 2018.

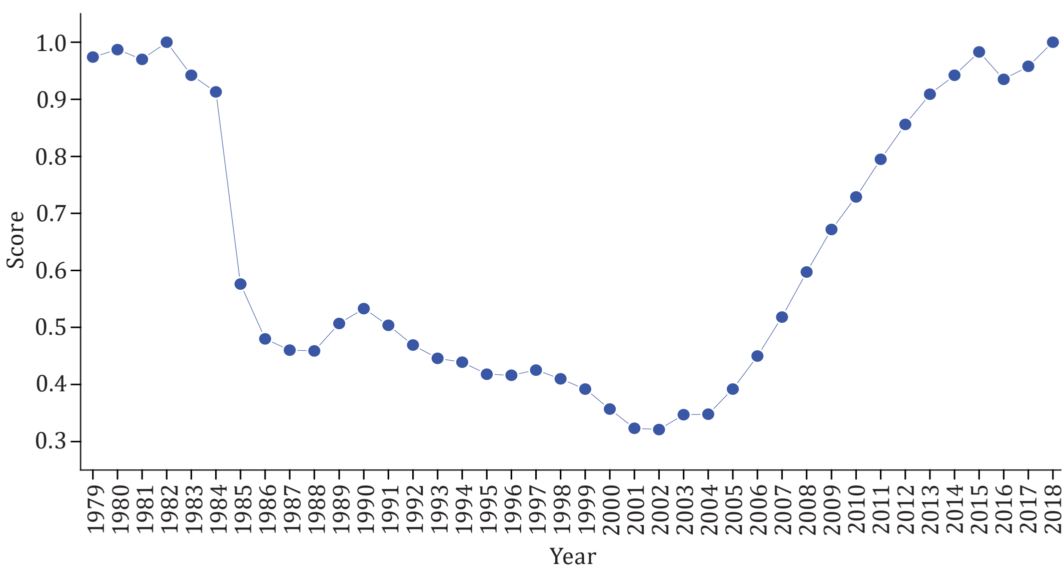

Figure 4. The performance score of Chinese road safety from 1979 to 2018

The turning point for the improvement in the performance of Chinese road safety occurred in 2002, which was consistent with the fitting results concerning the relationship between the road mortality rate and GDP per capita. In 2002, the number of Chinese road fatalities reached a peak, totalling 109 381. Thereafter, Chinese road fatalities have followed a downward trend, with the annual death toll consistently standing at approximately 60 000 in recent years. Road traffic injuries are still a major problem in China and require sophisticated prevention and control strategies. The Chinese government has made efforts to improve the performance of road traffic safety through the following measures: by substantially investing in road safety infrastructure; by introducing legislative and public education programmes to raise road traffic safety awareness and improve practice; and by improving pre-hospital trauma care and hospital treatment (Wang et al., 2015a; Wang et al., 2019b).

2.5. Limitations

This study had several limitations. First, many factors besides economic development may have had an impact on the road mortality rate, such as legislation, law enforcement, policy, motorization, urbanization, and the individual behaviours of road users. Therefore, interpreting trends based on the road mortality rate is a complicated endeavour. Furthermore, the data from police recorded road fatalities have some limitations, which may affect the results derived from this study regarding the association between changes in annual GDP per capita and annual changes in the road mortality rate. For instance, in China, it takes seven days for the number of recorded casualties to update after a road traffic accident has been reported.

Conclusions

This study used the Kuznets curve model to analyse the relationship between the road mortality rate and GDP per capita in China from 1979 to 2018. Road mortality is the product of the number of vehicles per person and the number of fatalities per vehicle. Data such as the number of road fatalities, the population, the number of vehicles, and the GDP per capita were all used for the Kuznets curve model. The reliability of the results was verified by applying the DEA-based road safety model.

Road safety development is closely related to economic growth in China. As GDP per capita rose from 1979 to 2018, the number of vehicles per person increased, thus following an N-shaped curve. The level of motorization also followed a significant upward trend in accordance with Chinese economic growth. The number of fatalities per vehicle decreased as GDP per capita rose from 1979 to 2018, thus following an N-shaped curve. Though this has begun to see a reverse trend since 2018, policymakers are implementing safety countermeasures to counteract this trend.

The relationship between the road mortality rate and GDP per capita in China follows an inverted U-shaped curve. While GDP per capita rose consistently between 1979 and 2018, the number of road mortalities increased between 1979 and 2002 but then decreased between 2002 and 2018. Road mortality rates in China increased as GDP per capita increased but decreased once GDP per capita exceeded 17.187 thousand CNY. Practical implementations such as the shift from high to lower risk motorized transport, road safety policies, and investments in health and transportation have had a positive effect on reducing the number of road fatalities. The turning point in Chinese road safety performance – as demonstrated by the Kuznets curve – occurred in 2002, which was consistent with the evaluation result from the DEA-based road safety model. Significantly, other industries – such as construction, chemical, and mining – can refer to the Kuznets curve and the DEA model for analysing the relationship between mortality and economic development in their sectors.

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