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The relationship between per capita GDP and road accidents in Sri Lanka: an ARDL bound test approach

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ABSTRACT

The objective of this study is to examine the relationship between road accidents and per capita GDP in Sri Lanka during the period of 1977 to 2016. The study examines the existence of Kuznets curve relationship between number of road accidents and per capita GDP in Sri Lanka, and the relationship of some other variables such as merchandise imports from various regions and different age group of population as well. The Auto Regressive Distributed Lags (ARDL) bound test approach is employed to analyse the time series data. The findings of this study confirm the existence of the Kuznets curve relationship between road accidents and per capita GDP. The results further reveal that there is a long-run relationship between road accidents and merchandise imports from high income and East Asian countries, urban population and age group of population 30-34 and 35-39. Coefficients of these variables are statistically significant at 1% level and positively associated with number of accidents in Sri Lanka.

Contribution/ Originality

The major contribution of this paper is that it applies the Kuznets theory to reveal the relationship between per capita GDP and road accidents in Sri Lanka. This study also investigates some new variables as determinants of road accidents, and then would supply new knowledge to the existing literature and contribute in policy making actions.

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1. INTRODUCTION

A number of fatalities and injuries from road accidents have been escalating for decades in Sri Lanka. This possibly affects in human capital and has become a serious concern in development trail. Though, it is seen as a very serious socio-economic problem, very less number of policy attempts are being carried out by the government to overcome the issue. Though, Sri Lanka has ended three decades of ethnic war, the deterioration in the stock of human capital caused by road accidents is becoming a serious threat for the future development. The road accidents make families to fall into poverty trap as families either loses their bread winners or members become permanently disabled. Further, the consequences of road accident pressurize the government to take care of activities such as health related expenditure, compensation to the victims, and structuring human capital and infrastructure development in traffic and transport departments.

As shown in Figure 1 the total number of road accidents increases from 1977 to 2003 and then declines till 2008. However, it shows an increasing trend again with fluctuation. Therefore, this study takes interest, whether this type of trend in the number of accidents is associated with economic development conception. Per capita GDP is proxies for economic development, and the relationship is tested by applying Kuznets theory which was initially produced to explore the relationship between income inequality and per capita GDP and then incorporated in environmental related studies. Therefore, this study investigates the inverted U-shaped relationship between road accidents and per capita GDP. The implication of this relationship is that an increase in per capita income initially causes an increase in vehicle population and develops road congestion where there is a positive relationship between road accidents and income of the people. However, when income and development meet a threshold level the awareness, safety and infrastructure development become concerned, which will decrease road accidents. A variable in this hypothesis is different from the literature where some studies have used Kuznets curve theory in accidents related studies. None of the studies have incorporated a number of accidents as a variable in their studies. Instead, Van Beek *et al*. (2000) constructed the relationship between prosperity and traffic accidents mortality and found that economic development first leads to a growing number of traffic-related deaths, but later becomes protective. Kopits and Cropper (2005a) also analysed the relationship between traffic fatalities and per capita income among the different classes of road users for 32 high income countries. Kopits and Cropper (2005b) examined the relationship between traffic fatality risk and per capita income. Taking data for 41 countries, Bishai *et al*. (2006) explores why traffic fatalities increase with GDP per capita in lower income countries and decrease with GDP per capita in wealthy countries. Paulozzi *et al*. (2006) analysed the relationship between economic development of a country and its motor vehicle crash mortality in 44 countries.

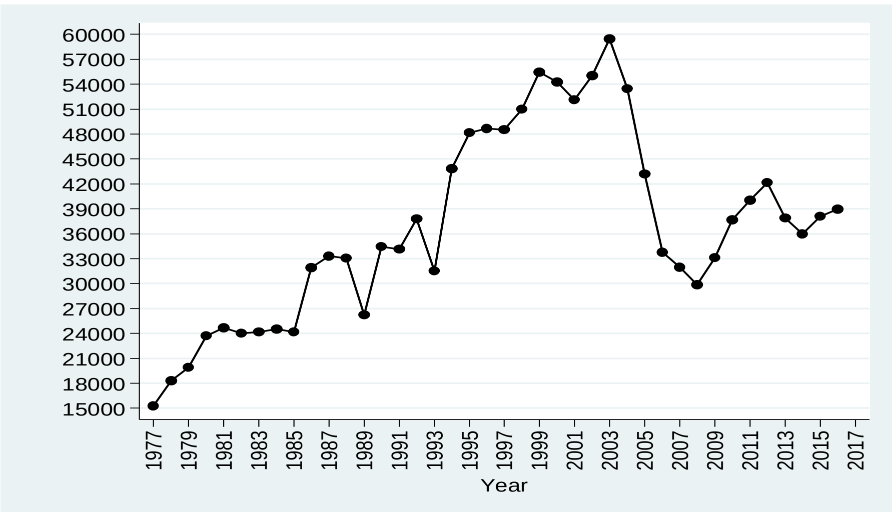

Figure 1: The trend of road accidents in Sri Lanka

Thus, this study takes number of road accidents and per capita GDP to investigate the existence of inverted U-shaped relationship, which will lead to conclude whether an increase in per capita GDP would reduce the number of road accidents in Sri Lanka because Sri Lanka is successful in increasing per capita GDP and perceived that she is in the development path performing in some development indicators progressive. Therefore, investigating whether economic development has Kuznets effect becomes a major objective of this study.

In addition to the investigation of the relationship between per capita GDP and road accidents, which is the main objective of this study, some other controlled variables such as trade and demographic variables which are presumed to be influenced on road accidents in Sri Lanka, are also incorporated in the econometric analysis. Thus, the econometric analysis in this study produces the direction and degree of influence of these controlled factors. In literature, a number of studies have included various controlled variables that influence on road accidents beside the per capita GDP. Jayaratne and Amal (2005) have discussed how the number and type of vehicle are associated with the number of road accidents. Walter and Thomas (2010) found that per capita income and elderly male drivers have negative associations with motor vehicle death rate in a state level analysis in the USA. Douglas *et al*. (2016) found that GDP growth in a given year causes additional road traffic fatalities in Botswana and Zambia. Mohammed and Amal (2013) in their study found that there is a strong relationship and effect between road traffic accidents and population, GDP, road miles, registered vehicle and number of driving license in Saudi Arabia. According to Aleksandra (2016) the commonest causes of road accidents in Serbia during 1999-2014 have been improper driving, speeding, and drunk and drive. Damien (1994) emphasized sleepiness is a major factor that causes road accidents in the USA. Shakil *et al*. (2014) found that length of paved road and household population has a positive association with road accidents in Bangladesh. Sotiris *et al*. (2014) found that the number of road traffic accidents increases significantly on the first two days following the announcements of austerity measures such as salary and pension cuts and an increase in direct and indirect taxes in Greece. Contrarily, *Chao et al.* (2009) found that traffic congestion has little or no impact on the frequency of road accidents on the M25 motorway in England. Persson (2008) suggested some factors such as poor road network, knowledge about traffic safety, mixed traffic flow system, poor legislation and failure of enforcement, poor conditions of vehicles in Ethiopia are responsible for road accidents. Adrian and Lisa (2006) had taken human factors which include stress and psychological states; sleep, fatigue, and alertness; and health status as determinants of road accidents. Hilde and Torbjorn (2002) measured personality factors such as risky driving, accident involvement, normlessness, sensation-seeking, locus of control and driver anger among Norwegian drivers, and concluded that those who scored high on sensation seeking, normlessness and driver anger reported more frequent risky driving and involved in both speeding and ignorance of traffic rules. Joannes *et al*. (1999) have taken young drivers lifestyle into consideration and found that the young drivers whose dominant lifestyle trait is alcohol consumption or drive without destination have high accident risk in Athens. In this line, adding findings into the literature, this study also incorporates trade and demographic variables to test the association with road accidents.

2. METHODOLOGY

2.1. Data and empirical model

The sample consists of annual time series data between 1977 and 2016. The duration of time series data is decided based on the availability of data, and 1977 is the period where Sri Lanka's economy was liberalized. The data for regressors were obtained from the World Bank Development indicators database, whereas the data for road accident variable were extracted from various sources such as Somasundaraswaran (2006), Department of Police, Sri Lanka, National Transport Commission Statistics, Sri Lanka (2015) and Kumarage *et al*. (2003). All series are transformed into the natural logarithm for econometric analysis. Table 1 provides a summary of the variables. The following two general specifications of the models are used in this study to have an empirical examination on the relationship between number of road accidents and controlled variables.

$$lnACC_t = \alpha_0 + \alpha_1 lnGPC_t + \alpha_2 lnGPC_t^2 \;\; + \alpha_3 lnIHI_t + \alpha_4 lnIEA_t + \alpha_5 lnISA_t + \alpha_6 lnUP_t + \varepsilon_t \ldots (1)$$

$$lnACC_t = \beta_0 + \beta_1 lnPOP1_t + \beta_2 lnPOP2_t + \beta_3 lnPOP3_t + \beta_4 lnPOP4_t + \Upsilon_t \qquad \ldots\ldots\ldots\ldots (2)$$

where *ACC* represents the total number of road accidents in Sri Lanka. The total number of road accidents includes fatal, grievous, non-grievous and accidents caused property damage only. *GPC* indicates per capita GDP. The model (1) incorporates exponent of GPC variable to investigate the existence of inverted U-shape relationship between per capita GDP and road accidents. That is, an increase in income levels is initially associated with a rise in road accidents, and then has negative association once the income level has exceeded the threshold level (Bishai *et al*., 2006). This is supported by the theory of Environmental Kuznets Curve (EKC). Therefore, the variable is incorporated to evidence the existence of an inverted U-shape relationship between number of road accidents and per capita GDP. *IHI* indicates merchandise imports as a percentage of total imports from high income countries whereas, *IEA* and *ISA* denote merchandise imports as a percentage of total imports from low and middle-income economies in East and South Asia, respectively. *UP* represent urban population as a percentage of total population. In model (2) male in different age groups as a percentage of total male population classified into four categories specified as *POP1*, *POP2*, *POP3* and *POP4* fall in the age group of 20-24, 25-29, 30-34 and 35-39, respectively. These variables are incorporated in the analysis because in countries young person comprises an increasing share of the driving population (Kopits and Cropper, 2005).

Table 1: Summary statistics

Variables	Observation	Mean	Standard Deviation	Minimum	Maximum
lnACC	40	10.4637	0.33048	9.6354	10.9928
lnGPC	40	7.3928	0.4616	6.6908	8.2512
lnUP	40	2.9189	0.0107	2.9067	2.9548
lnIEA	40	2.5514	0.5368	1.6464	3.4248
lnISA	40	2.4686	0.3712	1.7480	3.4670
lnIHI	40	4.0968	0.1369	3.7219	4.3603
lnPOP1	40	2.1978	0.0892	2.0098	2.2912
lnPOP2	40	2.1066	0.0697	1.9067	2.1731
lnPOP3	40	2.0164	0.0524	1.9018	2.0842
lnPOP4	40	1.9053	0.9940	1.7000	2.0129

2.2. Unit root analysis

Stationary test is only required to confirm that none of the variables follow I(2) because cointegration relationship can be performed using ARDL bound test method when the variables have integrated order of I (0), I (1) or combination of both. Therefore, stationary test is performed using Augmented Dickey Fuller (ADF) method to confirm integrated order of the variables. The optimum lag lengths are selected based on the Akaike Information Criterion (AIC). The results in the Unit root test as shown in the Table 2 confirm that no variables follow I (2). The results also show that the selected variables are integrated of orders either I(1) or I(0). Unit root test results shown in Table 2 ensure that none of the series in integrated at I (2).

Table 2: Unit root test results

Variables	Test statistic at Level	Lag	Test static at first difference	Order of Integration
lnACC	-2.287	1	-3.801	I (1)***
lnGPC	-0.936	1	-3.742	I (1)***
lnIHI	-0.809	1	-9.631	I (1)***
lnUP	-1.677	3	-4.677	I (1)***
lnIEA	-1.561	1	-5.793	I (1)***

lnISA	-0.922	1	-4.886	I (1)***
lnPOP1	-1.826	2	-3.056	I (1)**
lnPOP2	-3.660	1	--	I (0)**
lnPOP3	-3.022	1	--	I (0)**
lnPOP4	-3.325	1	--	I (1)***

*, **, *** indicate 10%, 5% and 1% significant levels, respectively

2.3. ARDL model

This study employs the Auto Regressive Distributed Lag (ARDL) bound test approach of cointegration to investigate the long-run relationship and dynamic interaction of the total number of road accidents with control variables. The ARDL which was presented by Pesaran *et al*. (2001) allows having efficient findings for long-run equilibrium and the short-run dynamic relationship between the non-stationary time series variables. It should be noted here that ARDL approach helps to identify cointegrating vector(s) and then which is reparameterized into Error Correction Method (ECM). The existence of the long-run relationship between the variables is confirmed by the bound F-statistic. The ECM gives the results of short-run dynamics (Emika and Aham, 2016). Thus, Unrestricted Error Correction Model (UECM) of ARDL is incorporated to examine the long-run and short-run relationship taking the following model into consideration.

$$\Delta lnACC_t = \delta_0 + \Upsilon_1 lnACC_{t-1} + \Upsilon_2 lnGPC^2_{t-1} + \Upsilon_3 lnIHI_{t-1} + \Upsilon_4 lnIEA_{t-1} + \Upsilon_5 ISA_{t-1} + \Upsilon_6 lnUP_{t-1} + \sum_{i=1}^{p} \nu_i \, \Delta lnACC_{t-i} + \sum_{i=0}^{q1} \partial_i \, \Delta lnGPC^2_{t-i} + \sum_{i=0}^{q2} \emptyset_i \, \Delta lnIHI_{t-i} + \sum_{i=0}^{q3} \mu_i \, \Delta lnIEA_{t-i} + \sum_{i=0}^{q4} \sigma_i \, \Delta lnISA_{t-i} + \sum_{i=0}^{q5} \vartheta_i \, \Delta lnUP_{t-i} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\Delta lnACC_t = \lambda_0 + \Pi_1 lnACC_{t-1} + \Pi_2 lnpop1_{t-1} + \Pi_3 lnpop2_{t-1} + \Pi_4 lnpop3_{t-1} + \Pi_5 pop4_{t-1} + \sum_{i=1}^{p} Z_i \, \Delta lnACC_{t-i} + \sum_{i=0}^{q1} \epsilon_i \, \Delta lnpop1_{t-i} + \sum_{i=0}^{q2} \text{x}_i \, \Delta lnpop2_{t-i} + \sum_{i=0}^{q3} \Omega_i \, \Delta lnpop3_{t-i} + \sum_{i=0}^{q4} \Gamma_i \, \Delta lnpop4_{t-i} + \Phi_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where δ_0 and λ_0 are constant and ε and Φ are white noise error terms. Δ denotes the first difference. The terms associated with the summation signs in both models represent the short-run dynamics, whereas Υ and Π are the long-run multipliers. STATA statistical software is used for the estimation of ARDL model, which estimates long-run and short-run relationships in one regression. As a first step, the unconditional ARDL model is estimated by setting a maximum number of lags permutations, which will lead to selecting optimum lag length. With the suggested optimum lag length, as a second step, the coefficients for long-run and short-run dynamic relationship and error correction term are obtained. As a third step, the ARDL bound test is estimated to confirm the existence of the long-run relationship between the variables. As the final step, beside bound test which is also considered as post estimation, the models go through further post estimation tests such as Durbin's-Watson d statistics to test for serial correlation and Breusch-Godfrey test for higher order serial correlation.

3. RESULTS AND DISCUSSION

Table 3: Estimated long-run coefficients

Regressor	Coefficients of Model 1 AIC (3,2,2,2,1,1,1,)	Coefficients of Model 2 AIC (3,1,1,1,1)
lnGPC	31.4047*** (0.000)	
lnGPC²	-1.9822*** (0.000)	
lnIHI	1.2986*** (0.004)	
lnIEA	0.3861*** (0.000)	

lnISA	-0.1748* (0.147)	
lnUP	76.0716*** (0.001)	
lnPOP1		0.1793 (0.847)
lnPOP2		0.9785 (0.346)
lnPOP3		2.2989*** (0.006)
lnPOP4		1.6634*** (0.050)
R-square	0.7863	0.6550
Adj R-square	0.5726	0.5031

*, **, *** indicate 10%, 5% and 1% significant levels, respectively

The unit root analysis clearly indicates that all variables are integrated order at I(1) or I(0). The ARDL bound test is performed with two models specified by models (3) and (4). Estimated long-run coefficients of both models are shown in Table 3. In the long-run, per capita GDP, merchandise imports from high income, East Asian countries, and the urban population are statistically significant at 1% level and found to have positive associated with road accidents. Surprisingly, the coefficient for merchandise imports from South Asian countries is negative and significant at 10% level. The coefficient value of the exponent term of per capita GDP is negative and significant at 1% level. This result confirms the existence of inverted U-shape relationship between number of road accidents and per capita GDP and reveals that an increase in per capita GDP is negatively associated with the number of road accidents in Sri Lanka after the thresh hold level. Teik *et al*. (2008) also analysed the Kuznets curve relationship between per capita GDP and motorcycle accidents and explored the inverted U-shaped relationship between the variables. Elizabeth and Maureen (2003) also noted the inverted U-shaped relationship between motor vehicle fatality and per capita income.

In second the model, population is classified based on the age group to test because when the drivers are relatively in young age, the reckless, immature, and drunk and drive, and less experience are believed as associated characteristics. The results reveal that age group of population 30-34 and 35-39 are positively associated with the number of accidents. The population age groups 20-24 and 25-29 are found to have not significant. These findings are not consistent with the findings of Joannes *et al*. (1999) that young drivers (18-24) both in Greece and elsewhere appear to have high rates of road accidents.

Table 4: Error correction representation of ARDL model

Regressor	**Model 1 AIC (3,2,2,2,1,1,1,)**	**Model 2 AIC (3,1,1,1,1)**
ΔlnACC (-1)	0.4802*** (0.009)	0.5150*** (0.013)
ΔlnACC (-2)	0.4063*** (0.013)	0.4416*** (0.014)
ΔlnGPC	-28.1837 (0.228)	
Δ lnGPC (-1)	-36.0103* (0.110)	
Δ $lnGPC^2$	1.9491 (0.211)	
Δ $lnGPC^2$ *(-1)*	2.3683* (0.0.114)	

ΔlnIHI	-0.4768 (0.295)	
ΔlnIHI (-1)	0.4116 (0.266)	
ΔlnIEA	-0.1847** (0.0.063)	
ΔlnISA	0.3886*** (0.005)	
ΔlnUP	-61.6081*** (0.003)	
ΔlnPOP1		3.6085 (0.333)
ΔlnPOP2		3.4929 (0.228)
ΔlnPOP3		-10.9063*** (0.059)
ΔlnPOP4		-15.3538*** (0.013)
Constant	-374.7255*** (0.000)	0.4240 (0.739)
ECM (-1)	-1.0994*** (0.000)	-1.3440*** (0.000)

The results of short-run dynamics from ECM of ARDL are reported in Table 4. The short-run adjustment process which is presented by ECM (-1) coefficients in both models have negative signs and are significant at 1% level. This indicates that the equilibrium is convergent to the equilibrium path responding external shocks. The estimated ECM (-1) indicates that how the disequilibrium in the previous year's shocks are adjusted back to the long-run equilibrium in the current year. The results of bound test approach as shown in Table 5 confirm the existence of the long-run relationship between the variables. The F-statistic 6.563 and 6.718 for the models (1) and (2) are above the 1 percent critical values reject the null hypothesis of no co-integration.

Table 5: ARDL Bound Test for the existence of co-integration

Model	F-Statistic	1% Critical Value		5% Critical Value		10% Critical Value	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
1 with k=6	6.563	3.15	4.43	2.45	3.61	2.12	3.23
2 with k=4	6.718	3.74	5.06	2.86	4.01	2.45	3.52

4. CONCLUSION

The study examines whether the Kuznets relationship exists between per capita GDP and road accidents in Sri Lanka. Using annual time series data extracted from various sources, including the World Bank development indicators database, ARDL bound test approach is employed for data analysis. This study adds its findings to the literature that there is an inverted U-shaped relationship between per capita GDP and number of road accidents in Sri Lanka. In addition, the findings also conclude that merchandise imports from high income and East Asian countries, urban population aged group 30-34 and 35-39 are found to have effect on road accidents. Therefore, a good indication is proven that Sri Lanka is led to have less and less number of road accidents in future coping up with the income increase of the people. However, it has to be emphasized that the number of fatalities and injuries are reported to be increasing. Thus, this study also suggests for an investigation of the factors that determine increasing trend in fatalities and injuries, even though the number of road accidents may decline further in Sri Lanka.

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