Open University of Cyprus

Faculty of Economics and Management

Joint Master's Degree Program *Enterprise Risk Management*

Master's Thesis

The Effect of the Economy on Risky Driving

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Thesis Supervisor
Antonios Targoutzidis

May 2021

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A Thesis submitted in partial fulfilment of the requirements for the obtaining of Master's Degree

in Enterprise Risk Management

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Summary

Risky driving is a current social issue which afflicts societies, state governments and in many cases leads to morbidity when it comes to fatal traffic accidents. There are various categories of stakeholders that are affected both directly and indirectly such as governmental emergency services, people involved in road accidents, their families and lovely ones and insurance organizations.

This study is mainly devoted to interpret the data collected in global scale, in European Union scale, and in regional scale by examining the paradigm of Greece. It will be examined the relationship between prosperity and traffic accident mortality in two dimensions; that is, firstly by comparing different countries for certain predetermined years, and in the second place, by investigating how an economic recession may influence the number of road accidents. The data utilized in this text are retrieved by official organizations: Eurostat, IMF, WHO, ELSTAT (Hellenic Statistical Authority) and World Bank.

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Table of Contents

Chapter 1
Introduction

Economic development is one of the key determinants that plays a pivotal role on mortality. Rising living standards in a population contributes to a pattern attributed to chronic diseases with lower mortality levels. Nowadays, transition has been completed in the industrialized world unlike in the developing countries. General evidence indicates that economic growth is highly associated with upgrade in the health and sanity level of populations. Economic growth, however, has led to deterioration in the health of a population in the developed world. (Beeck, Borsboom, & Mackenbach, 2000)

The post-World War II period (1945–1970) was not followed only by economic growth, but also a significant increase in cardiovascular diseases and traffic accidents has taken place. Currently, however, in the developed world, the most prosperous countries are linked to the lowest levels of cardiovascular mortality. Similarly, to the finding of cardiovascular diseases field, the cross-sectional associations between macroeconomic factors and traffic accident mortality in developed countries have changed over time. (Beeck, Borsboom, & Mackenbach, 2000). But is that really the case for the road traffic accidents?

Road accidents are unforeseen and involve uncertainty. Those accidents are caused by numerous factors that rely on various variables, such as: no priority given to pedestrians, no priority given to vehicles, the illegitimate crossing of pedestrians, deviations of bicycle users, exceeding speed limitations, deviations of heavy vehicle drivers, and so on. It can be argued that road and traffic accidents are defined by a set of variables, both known and unknown ones, which are more subtle. Accident reduction and road safety constitute a major and alarming concern for public health. (Savolainen, Mannering, Lord, & Quddus, 2011). Traffic accidents as an indispensable societal issue has led to several cross-sectional studies to have been conducted to identify the association of prosperity with mortality.

So far, there have been studies of which outcomes that contradict one with another. (Beeck, Borsboom, & Mackenbach, 2000)The gross national product per capita shows a negative correlation with the number of traffic deaths in one country, that is; there is a strong negative association between prosperity and the number of traffic deaths per million habitants on global scale. In other words, prosperity appears to be a key factor of traffic accident mortality. Bibliography also indicates a negative association between prosperity and traffic accident mortality on less developed and middle-income countries. (Organization, ROAD SAFETY:, 2017) However, a research referring to all countries (those for whom transparent data are disposable online issued by reputable official worldwide organizations) will be conducted and significant inferences will be drawn.

This Thesis is composed to identify the correlation, if any, between risky driving and economy. Bibliography indicates that people averse to taking risks during downturns and recessions when it comes to investing (Gennaioli & Shleifer, 2018) and on the contrary, during economic growth they become risk prone (J.Klasing, 2014). In the thesis will be examined thoroughly whether in case of risky driving the abovementioned statements come true. This could be measured by getting data for countries concerning road traffic fatalities per million inhabitants in global and European (EU states) scale and applying econometric models. It could also be examined and reviewed by deploying a certain example of a country by demonstrating time-series graphs and giving inference.

For comparisons between countries or regions (or within a single country over time), the utilization of death rates per million inhabitants more precisely reflects the size of the issue than absolute numbers alone. Using of the total number of deaths alone could result to misleading inference, because the comparisons of populations of unequal size, cannot quantify the outcomes. (Organization, Road Safety: Basic Facts, 2017)The amount of single occurrences of accidents, without any reported death, does not constitute a significant measure of number of accidents, since there is not an objective scale of the severity of material and physical damage. Moreover, thousands of traffics do not be reported to the authorities by the drivers and users involved, especially in case of minor type of accidents. In many cases those type of accidents even when reported, are not recorded and tracked by official authorities to any system of data collection. (Beeck, Borsboom, & Mackenbach, 2000).

The fourth chapter of the Thesis, is divided into three main parts. In the first and the second parts is used econometric analysis for cross-sectional data for tenths of countries. More specifically, in the first part, cross-sectional data are collected by the Eurostat referring to the Real GDP per capita per EU country in years 2010, 2018 and 2019. There are also collected data of accidents pertaining to demises by road accidents by the same source via Europa.eu portal. On the same portal there is a graphic presentation of the Road Quality index (originating by the World Economic Forum Global Competitiveness Report) for all state members countries, which is also a parameter to be investigated for the association between quality of road network and road accidents.

In the second subchapter, the same models as in the first subpart are applied for data collected in global scale. After an extended research of cross-sectional data for all countries in the world, it is inferred that there is a high level of awkwardness to retrieve reliable data for a certain year pertaining simultaneously to the GDP per capita and fatality index. Due to the aforementioned reason, cross-sectional data are retrieved by reputable worldwide organizations, namely, the World Health Organization (WHO) and International Monetary Fund (IMF). Those data are based on current estimations (October 2020) and predictions of both organizations on an annual basis (whole 2020). Both for EU and global scale research, the indicator of road accidents to be taken into account is demises or fatalities per million inhabitants.

The Ordinary Least Squares estimate method is introduced in the third chapter, and applied in the fourth part, for all the above-mentioned models used. When Real GDP per capita is utilized as the independent variable, both linear and log-log regression models are applied. The log-log regression models give inference concerning the elasticities of the independent variable X: Real GDP per capita, with respect to the dependent variable Y: demises. The theoretical and technical framework applied is structured based on academic knowledge derived by the first-year academic module ERM502: Advanced Quantitative Methods for Managers, along with the module 0204: Advanced Econometrics (Master's Degree Course-6ECTS), attended remotely at Justus Liebig University Giessen as part of the participation in the Virtual Mobility Program. Lecture notes from both modules have been deployed and some extra material was extracted by the privately owned course book *Econometric Analysis, third edition by William H. Greene*.

In the third subchapter, data from time series are retrieved for a specific European Union country. Greece is found to have been the most crisis affected country amongst the EU state members in terms of total output produced; that is, Real GDP per capita, GDP per capita inflation adjusted. The yearly percentage rate of growth for Greece and the EU are presented in the same graph according to data retrieved by the World Bank. In that section of the Thesis, Greece has been chosen as a paradigm of a country having incurred prolonged economic recession in order to investigate any potential association of the constant decline in GDP with the decline in the number of road accidents in the long-run perspective. Both time series of demises and GDP evolution are drawn in a common time series graph so as to illustrate the trends and compute and compare the corresponding downward slopes during the period of acute economic recession. The number of demises caused by road accidents that is used is in absolute numbers, not per million inhabitants, since the GDP is not in "per capita" t

1.1 Economics and economy – Definitions

Economics is a social science concerned chiefly with description and analysis of the production, distribution, and consumption of goods and services. (Dictionary M.-W. , 2021)
Economics is divided into two categories: microeconomics and macroeconomics. Microeconomics is the study of individuals and business decisions, while macroeconomics looks at the decisions of countries and governments. Though these two branches of economics appear different, they are actually interdependent and complement one another. Many overlapping issues exist between the two fields. (Potters, 2021). In economics terms, a prolonged and very deep fall in total output is called depression, as opposed to recession, that is; a period of economic short-term downturn.

As per Economy, is the field of economics that studies the long-term growth for a certain region at a certain period of time. The major macroeconomic factors measuring an Economy are GDP, that is; Gross Domestic Product, unemployment rate, CPI, namely Consumer Price Index and Inflation rate. (Paul & Robin, 2006)
According to the Okun's law, exists a strong negative relationship between the change in GDP and unemployment rate. Additionally, according to the short-run Phillips Curve, namely SRPC, there is a negative relationship between the inflation rate and unemployment level. (Paul & Robin, 2006)

Since three out of four major macroeconomic factors are directly or indirectly correlated one with another, for the purpose of this Thesis will be utilized the GDP indicator as a reliable and consistent one. More specifically, the factor will be adjusted in "per person within an economy" terms, that is the GDP per capita. The effect of inflation could be "absorbed" by using the Real GDP per capita index which is the GDP per capita inflation adjusted. This is achieved by considering a certain year as a reference point and for the rest years inflation is taking into account per each country.

1.2 Questions arising and significance of the research

Some questions posed are to be answered should enough evidence results by the research conducted.

- Is infrastructure a key indicator of low level of fatal traffic accidents?
- Are there any variations among different countries?
- What are the results in a global, European and regional context respectively?
- In prosperity a key parameter which directs people to take more risks than in a downturn?

The global burden of road fatalities and morbidity might be proved to follow complex demographic, demographic and temporal patterns. While lives loss from traffic accidents is a major and essential topic of global scale, there has been not been conducted any recent comprehensive research that assesses and computes estimates for all countries, age groups, and sexes over recent years. (James, 2020)

The research is imperative, since fatality and morbidity of accidents in a global scale has become an epidemic. Consequently, should enough evidence be traced regarding the interconnection between these two affairs, state governments and individuals may become alert. The adaptation of measures both in national and global scale in the direction of reducing the number and fatality rates are judged to be indispensable.

1.3 Stakeholders involved in road accidents and sequence of events

Most injuries are the outcome of a sequence of events representing a sequence of activities, rather than a discrete circumstance in time defined as the event. A twodimensional matrix represents efficiently the stakeholders and classifies them into various categories according to the chronological order that a road incident happens and the general group in which they belong. Therefore, it is critical that the columns and the rows of the matrix be defined prudently. (Runyan, 1998)

Frequently, an event may be defined in a variety of ways depending on one's point of view. This is arbitrarily chosen; however, it is pivotal in order to anchor one's perception about what comes before and after the event. Once the two dimensions of the matrix have been prudently defined, brainstorming in individual or group level is handy to generate ideas about interventions in all cells. If participants are from different disciplines, they will bring different perspectives to the problem and to solutions, enriching the overall pool of ideas. By implementing the principles of brainstorming in which all ideas are stored and taken into consideration without commenting before discourse, the whole procedure could yield a vast variety of options. (Runyan, 1998)

William Haddon Jr invented a conceptual model, the Haddon matrix, implementing the fundamental principles of public health to the critical issue of traffic safety. The model had been initially developed and utilized as a tool to contribute in generating ideas for prevention of injuries of many types. In essence, this matrix model provides a forceful framework for realizing the origins of injury issued and for identifying and defining numerous counter-measures to address those issues. Nevertheless, users are the decision makers for themselves, from their perspective, among the alternatives. A third dimension might be optionally added to the matrix model to facilitate its utilization for decision making which however will not be considered in this text. (Hines, 2016)

The Haddon’s matrix consists of three rows and four columns combining public health concepts of host-agent-environment as targets of change highlighting the chronological steps of prevention; that is, primary, secondary, and tertiary. Moreover, the three factors defined by the columns of the matrix pertain to the interacting factors which contribute to the road accident process. Physical environments include all the characteristics of the setting in which the injury event takes place (for example a roadway, building, playground, or sports arena). Social context refers to legal practices and norms perceived in the culture are appertained to as the social environment. (Hines, 2016)

Haddon's Matrix – Road Accidents' Stakeholders

		Human	**Vehicle and Equipment**	**Environment**
Precrash	Accident prevention	Educational system Road users Government	Government Users Vehicle manufacturers	Society Government Road users Road manufacturers
Crash	Injury prevention during accident	Road users	Vehicle manufacturers Vehicle users	Government Road users Road manufacturers
Post-crash	Life conservation, care	Government Roadside assistance organizations Insurance organizations	Vehicle manufacturers Road manufacturers Government	Government Society Road manufacturers

In the Haddon's matrix, only the key stakeholders are being referred. Government pertains to governmental services such as police, emergency and health services and other services in charge for the technical inspection of crashed vehicles. Those emergency services are placed under government, because of their crucial role they play in society and since the government is, explicitly or implicitly, their employer. In the government services, is also included the technical inspection services which in many developed countries intervene when an accident has occurred. Road users in considered a vast target group on which the measure applies. This category includes vehicle drivers and passengers, pedestrians, cyclists, public transportation users, motorbike users, pre-drivers, children, handicapped users, the elderly, etc. (Hines, 2016)

1.4 Risk, risky driving and risk perceptions

Risk is defined as the possibility of something unfavorable happening. (Dictionary C. , 2021) Another definition of Risk is the possibility of loss or injury. (Merriam-Webster, 2021)Risk involves uncertainty about the effects of any activity with regard to something that human value e.g., health, prosperity, well-being, environment or property, often focusing on unforeseen, negative and unexpected consequences. (Analysis, 2020) There are multiple definitions given, but the international standard definition of risk for common sense in various applications is the “effect of uncertainty on objectives”. (73:2009, 2009)Risk perception is the subjective judgement one makes about characteristics and severity over a risk. In other words, risk perceptions refer to beliefs about potential harm or the possibility of loss. Risk perceptions are different for the real risks since they are affected by a vast range of affective, cognitive, contextual and individual factors. Several theories have been developed so far to clarify why different people make different estimates of the dangerousness of risks. (Maksim Godovykh, 2021) Three major families of theory have been developed; that is, sociology approaches (cultural theory), psychology approaches (cognitive and heuristics), and interdisciplinary approaches (social amplification of risk framework). (Paul S. , 2016)

Risky driving pertains to the engagement of risky behaviors of a driver which may lead to unfavorable, unforeseen and unpleasant incidents, such as a fatal road accident. (Assembly, 2016)There are various categories of risky driving, one of which is drunk driving. A second classification of risky driving is the drug-impaired driving, in which the driver prescribes herself with drugs and medication, both legal and illegal ones, which in return might impair her ability to drive safely. Some medication is considered safe itself, but might impair one’s driving ability if combined with another one. Driving a vehicle while being drowsy constitutes a highly hazardous activity too. Seat belts contribute to saving lives when it comes to car accidents and distracted driving might lead to the opposite outcome, (Transportation, 2021) Poor car condition and/or poor road infrastructure are also considered pivotal parameters that contribute all together to the occurrence of road traffic accidents. The road infrastructure and its attribution to crashed is one of the parameters to be considered in this text.

For over twenty years, speeding has been involved in approximately 33% of all road traffic fatalities. In 2018, speeding was a pivotal factor in 26% of all traffic fatalities in the USA. Speed also deteriorates safety even when one drives close to the indicated speed limit but too fast regarding the road conditions, such when a road is under ongoing repairs, when the weather is bad or in an area without sufficient lit at night. (NHTSA, 2019) This could be reaffirmed by the Momentum definition in Physics a doubled speed causes momentum to double all the other held constant; that is;

$$\vec{P} = M * \vec{V}$$

"When a collision occurs in an isolated system, the total momentum of the system of objects is conserved. Provided that there are no net external forces acting upon the objects, the momentum of all objects before the collision equals the momentum of all objects after the collision." (Halliday, Resnick, & Walker, 2001) Which practically means that the momentum of two colliding vehicles doubles when their speeds doubles.

Chapter 2
Literature Review

For the completion of the research has been realized a multi-dimensional exploitation of academic sources, privately owned academic books, academic notes in econometrics, dictionaries, reports, officially issued data, along with newspaper articles of reputable publishers. The academic sources were mined mainly via the portals google scholar, researchgate.net and web ebsco-host, getting access with the academic credentials of Open Athens, granted by the Open University of Cyprus.

The traffic accident mortality is compared to cardiovascular diseases in bibliography, so as to highlight the volume and the significance of the research conducted (Beeck, Borsboom, & Mackenbach, 2000). The mortality caused by traffic accident is said to be an epidemic and is found to be negatively correlated to the prosperity since the early of 1960s. Additionally, the importance of conducting a research using averages instead of absolute numbers is underlined; that is, demises per million inhabitants.

Definitions of the key words, economy, economics and elucidations are provided by literature, so as not to be inferred distorted conclusions. Merriam-Webster dictionary is cited to give the definition of Economics and the Investopedia elucidated the difference between microeconomics and macroeconomics. An extend usage of the owned book Economics of Paul Krugman and Robin Wells has been done, so as to the ideal economic indexes be retrieved in order to introduce and define some terminology. That book contributed in the direction of comprehension of the majority of academic background and knowledge concerning the fundamental concepts of economy, especially in the branch of macroeconomy.

The research conducted is of great significance, since the complexity of the patterns that road accidents follow, along with the morbidity caused as a result of them constitute a major issue for concern (James, 2020). Similar concerns had been reflected and classification of the stakeholders involved in a road accident and in a bi-dimensional matrix were proposed. (Runyan, 1998)In 2016 Hines Kristin, presented the Haddon matrix, crafted in 1970 by William Haddon broadly used to link and classify the factors that contribute before, during and after a road accident takes place.

The definition of risky driving is introduced by the governmental portal of the Northern Ireland Niassembly.gov.uk. The most remarkable human factors attributable to the cause of road accidents are various but not limited to neurological, psychiatric, mental and cardiovascular disorders along with driving under influence of alcohol and drugs (both legitimate and non-legitimate ones). Those factors are crossly researched by the NHTSA; that is, the Transportation Department of the USA Department and the 3 books of Theoretical Training of Candidate Truck Drivers, Theoretical Training candidate Bus drivers and Theorical Book of Certificate of Professional Competence for truck drivers (PEI-ΠΕΙ) issued by the Hellenic Ministry of Transport and Communications.

In this text, it is proved the nexus between prosperity and number of fatalities attributed to road accidents. The outcomes of this thesis are congruent with the findings of other researches cited. They will be proved by the application of Econometrics models based on large pools of data referring to tenths of countries. The core findings pertain to the influence that GDP exerts to the formation of the number of road accident fatalities. The higher the total output a country produces during a certain period of time, the less the demises it experiences as a result of vehicle crashes and vice versa. Bibliography, indicates that low-income and medium-income nations account for about 85-95% of the global road accident fatalities, even though these countries have only about half the world's fleet of vehicles. In other words, a positive association between road accident mortality and lack of prosperity has been found in cross-sectional studies focusing on poor and middle-income nations. (Organization, Road traffic injuries, 2020) (Carriero & Azeredo, 2018) The death rate attributed to road accidents is three times greater in low-income countries as compared to high income countries according to WHO. (Organization, Road traffic injuries, 2020)

Another, remarkable and contradicting finding is the influence of an economic recession to the number of demises by road accidents. The paradigm of Greece is examined and implemented through time-series graphs, so as to identify this dimension, and the respective findings are discussed and compared to the bibliography cited. In this dimension of the research is investigated whether economic growth or recession may influence the number of road accidents, and consequently, the demises, over a certain period of time. In general, as countries develop, death rates usually decrease, particularly for diseases that affect the youngsters. However, deaths attributed to road accidents constitute a notable exception: the growth in numbers of motor vehicles that often is accompanied by economic growth, often brings an increase in road traffic accidents (Kopits & Cropper, 2003) Moreover, the number of accidents was found to be increasing over a period of two years as an outcome of overcoming the impact of the economic crisis and consequently, the increase in the number of vehicles in Romania (Cioca & 3, 2017). On the contrary, in Greece a notable decrease was observed in the number of road traffic fatalities due to the constant fall of GDP during the period 2010-2017 (Nea, 2018) (Naftemporiki, 2016). A relationship does exist between annual mortality rate changes and annual GDP changes. (Yannis, Papadimitriou, & Folla, 2014) In other words, a strong positive relationship between increase of annual GDP and mortality rate increase was found, as well as a statistically solid relationship between annual GDP decrease and fatality rate decrease.

Chapter 3

Methodology

The validity of data in micro-econometric analysis in general is expected to be high. In the majority of cases, it is likely to directly observe the variables which we are interested in, instead of aggregates. For example, if marketing scientists want to analyze data concerning sales of a new product, they can use purchasing data collected by electronic scanners at the counters of commercial enterprises. Also, there are often large data sets disposable in the form of cross-sectional or panel observations.

Moreover, we can more easily conduct an experiment with a control group and a treatment group. For instance, we can modify the advertisement in only some of the commercial enterprises. Alternatively, we can give some patients a newly developed drug while others get a placebo. This is usually not likely for macroeconomic time series data of a country or for panel data. In that case the data are disposable online can be considered highly transparent if they derive from a reliable source.

The methodology to be implemented in this text is Econometrics Analysis applying the OLS method; that is, Ordinary Least Squares divided into 3 main parts. In essence, in the research Regression equations will be presented both linear and log-log transformed models, where the Y is defined as the depended variable, that is; the variable to be explained, or else, the regressand or endogenous variable, in our case; the number of fatalities (demises) from road accidents. The explanatory variable or regressor or exogenous variable is X. In essence, we are interested in measuring the effect of X on Y. The effect of X, is designated as a macroeconomic indicator and Y as risky driving. Risky driving will be considered in terms of road accidents deaths per million inhabitants as stated previously. The macroeconomic indicator -variable X- is Real GDP per capita

The regression model to be used is $Y_i = \beta_0 + \beta_1 * X_i + \varepsilon_i$ for i = 1, ..., N

- Y is the dependent variable
- X is the independent/explanatory variable
- β is called the regression parameter of X of the model
- ε is the error term of disturbance, or else, it is the part of Y that is not determined by X

The effect of X on Y in mathematical terms is the derivative

- $\frac{\theta\psi i}{\theta\chi i} = \beta_1$

To make matters clear, if x changes by one unit, under the ceteris paribus assumption (c.p.), y changes by β_1 units. The ceteris paribus assumption suggests that all the other factors that may influence y remain constant.

We do not have the values for β and ε but we have data on (y_i , x_i) for our observations collected i = 1,…,N

The parameter β will be estimated using the OLS estimation method, the estimated parameter is called estimated coefficient and is labeled as $\hat{\beta}$.

The value of y that is explained by x is called the predicted value and occurs;

$$y_i = \widehat{\beta o} + \widehat{\beta 1} * \chi_i$$

The unexplained part is called the residual and is defined as

$$\hat{\varepsilon}_i = y_i - \hat{y}_i = y_i - \widehat{\beta o} - \widehat{\beta 1} * \chi_i$$

The explain and the unexplained parts add up;

$$y_i = \widehat{\beta o} + \widehat{\beta 1} * \chi_i + \hat{\varepsilon}_i$$

Because we have collected cross-sectional data of the form (y_i, x_i) for i = 1,…, N our model is;

$$y_i = \beta_1 * \chi_i + \varepsilon_i$$

which in Matrix notation is denoted;

$\boldsymbol{y} = \boldsymbol{X}\beta + \varepsilon$, where y and ε are (N x 1) – vectors (matrices) and X is a (N x k)-matrix, so that they satisfy the matrix multiplication properties:

$$(N \text{ x } 1) = (N \text{ x } k) \text{ x } (k \text{ x } 1) + (N \text{ x } 1)$$

$$(N \text{ x } 1) = (N \text{ x } 1)$$

Indeed, as expected a (N x 1)-matrix equals to a (N x 1)-matrix.

The OLS method implemented requires that the OLS is the BLUE, or else, the Best Linear Unbiased Estimator. The OLS assumptions for both linear and log-log regression models regression models in 3.1 and 3.2 to be applied for each specific year are the following:

- The underlying relationships between the X explanatory variable and Y dependent variable is linear (this also applies for the new variables arising by the log-log transformed data)
- Correct model specification: $Y= \beta_0 + \beta * X + \varepsilon$, there are not any missing explanatory variables
- Error values (ε) are statistically independent, that is; $E[\varepsilon | X] = 0$
- $E[\varepsilon\varepsilon' | X] = \Omega = Diag[\sigma_i^2]$ (no autocorrelation of error terms)
- $\sigma_i^2 = \sigma^2$: (homoskedasticity)
- Full rank of X (identification)

- Error values (ε) are normally distributed for any given value of x
- The Mean value of errors is zero, that is; $E[\varepsilon] = 0$
- The probability distribution of the errors has constant variance

Unbiased estimator means that:

$$E[\hat{\beta}|X] = \beta$$

Where $\hat{\beta} = \beta + (X'X)^{-1} X'u$ in matrix notation and

$$E[(X'X)^{-1}X'u|X] = 0,$$

since $E[u|X] = 0$ from assumption of OLS

The Covariance:

$$Var(\hat{\beta}|X) = \sigma^2 (X'X)^{-1}$$

The OLS estimator is considered efficient if $Var(b|X) - Var(\hat{\beta}|X) \geq 0$

Definition of *plim*:

A series of random variables X_N is said to converge in probability to a constant c, "plim $X_N = c$", if for each $\varepsilon > 0$ occurs:

$$Lim_{N\to\infty} Prob(|x_N - c| > \varepsilon) = 0$$

According to the *Gauss-Markov Theorem*, for the linear regression model with matrix of regressors, or else independent variables **X** the OLS estimator $\hat{\boldsymbol{\beta}}$ is the unbiased linear estimator of β with the smallest variable. Nothing changes for the log-transformed data, since the model occurring is a linear model based on the logarithmic transformations of the data.

Unlike, disaggregate level data, that is; microdata which are mainly collected for organizational purposes, in case of Panel Data the Ordinary Least Squares "OLS" method cannot be applied, because the error is correlated to the explanatory variable X across various years. Therefore, the linear equation $Y_i = \beta_0 + \beta * X_{it} + \varepsilon_t$, where t=time, is used instead of $Y_i = \beta_0 + \beta * X_i + \varepsilon$ which would have been used in OLS for microdata. Nevertheless, if the pooled estimation is applied for a sequence of years, the parameter of t=time is not taken into account and therefore it is inferred that the estimation model treats the data in the same manner as if OLS is applied.

However, in this text the OLS method will be applied for cross-sectional data selected (for a specific year each time), so as to highlight the difference in absolute number among European state members in each single year, that is; 2010, 2018, 2019. Transparent data for all years within the interval [2010,2019] could not be retrieved by any reliable source. In case this could have been achieved, the 3 core methods for Panel data would have been applied, since they would fit better the data collected. Those models are Pooled Estimation, Fixed Effects and Random Effects models.

In all regression models applied, it is defined only 1 independent variable each time. In all cases the dependent variable **Y** is designated as follows:

- Number of demises per million inhabitants (road accident fatalities per million inhabitants)

The independent variable **X** used, one for each model selected, in this text are:

- Real GDP per capita (GDP per capita inflation adjusted), which is the main indicator of the total output a certain economy produced within a certain period of time (year), divided by the total population of that economy (country) – in model applied for EU countries
- GDP per capita – in model applied in global scale
- Road Quality Index according to the World Economic Forum Global Competitiveness Report – in model applied for EU countries

The data are retrieved from transparent online sources appertaining to highly reputable official global organizations: The World Health Organization, the International Monetary Fund and the Eurostat. The indicators of road accident fatalities are expressed by the number of demises by million inhabitants. When that indicator is choses, the corresponding correct indicator referring to GDP, is the GDP per capita, so that the total population of each country is not taken into account. The Road Quality Index pertaining to the EU countries rating of their Road Network is based on a survey conducted by the World Economic Forum using a scale of [1,7]. The less rated a country for its network, the less the quality of its road network.

In the log-log transformed regression models applied, the data of the above-mentioned variables are transformed into logarithmic values by computing the corresponding natural logarithm LN values of the data. The utility of those transformations is giving better inference by describing the elasticities of the variables X with respect to the respecting variables Y. In most cases applying log-log transformed models, better specifications are observed.

Specification Tests

Correct, model specification:

a)Linearity

Ramsey's Reset Test:

H_0 : relationship is linear

H_1 : relatonship is nonlinear

This specification test requires the reapeat of the regression with the powers of estimated variable $\hat{y}$ as regressors to check if they can explain something:

$Y = X*\beta + Z*\alpha + \varepsilon$ with $Z = [\hat{y}_i^2, \hat{y}_i^3, ..., \hat{y}_i^n]$

If the initial regression model is of the form

$y_i = \beta_i + \beta_2 * x_2 + \beta_3 * x_3 + ... + \beta_k * x_k + \varepsilon_i$, $i = 1, …, n$

adding the variable $\hat{y}_i^2$ to the linear regression model occurs:

$y_i = \beta_i + \beta_2 * x_2 + \beta_3 * x_3 + ... + \beta_k * x_k + \gamma * \hat{y}_i^2 + \varepsilon_i$, i = 1,..., n

The core idea is to test the joint significance of additional regressors

A hypothesis test is contucted:

Null Hypothesis: $H_0 : \gamma = 0$

Alternative Hypothesis: $H_1 : \gamma \neq 0$

b) autocorrelation

Durbin-Watson Test

H_0 : no autocorrelation

H_1 : positive or negative autocorrelation

There are three cases:

- DW > 2 negative autocorrelation exists
- DW < 2 positive autocorrelation exists
- DW ≈ 2 no autocorrelation exists

However, empirically, we are more "tolerant" and state that if 1.6 ≤ DW ≤ 2.4, no autocorrelation exists.

c)Homoscedasticity

White-Test

H_0 : homoskedasticity exists

H_1 : heteroskedasticity exists

It is examined the Chi-Square

If the prob. of Chi-Square < 0.05 = α, the null hypothesis is rejected and there is enough evidence of misspecification

d) Distributional assumptions

Jarque-Bera Test

H_0 : normal distribution

H_1 : non normal distribution

JB = $\frac{N-K}{6} * \left(S^2 + \frac{(K-3)2}{4}\right) \backsim X_z^2$

The null hypothesis H_0 is rejected if JB > 6 for $\alpha = 0.05$

e) Endogenous regressors exist in the model

Hausman Test

The Hausman test is applied in a situation where estimators from an OLS regression to identify whether the potentially endogenous regressors as well as estimators from an instrument variable regression with valid instruments are available.

The core idea is that X the independent variable should be independent from error u and it has to be demonstrated that $X*u$ are correlated in OLS.

$\hat{u}$ * X = 0 : no correlation by construction

$\hat{u}$ * X * $\hat{v}$ is not necessarily zero

The procedure:

We regress Y on Y with residuals $\hat{u}$: $Y = X * \beta + u$

Regress potentially endogenous X on instrument Z with residuals $\hat{u}$: $X = Z * \beta + v$

We regress $\hat{u}$ on X and $\hat{v}$

The test Statistic is $L * M = N * R^2$ of the second regression

Null Hypothesis H_0: all regressors are exogenous (or else they have explanatory power)

Under H_0 the test statistic is asymptotically $\backsim X_q^2$

Moreover, the Endogeneity of a regressor is checked:

If OLS is inconsistent

We compare OLS and 2SLS:

H_0 : $plim(\hat{\Theta} - \bar{\Theta}) = 0$ or else no endogeneity exists

The assumptions under the null Hypothesis is:

$H_0 : \sqrt{N} * (\hat{\Theta} - \bar{\Theta}) \rightarrow N\,(0, Var_H)$

Hausmann Statistic: $H = (\hat{\Theta} - \bar{\Theta})' * (\frac{VarH}{N})^{-1} * (\hat{\Theta} - \bar{\Theta}) \backsim X_q{}^2$

Estimator for Var_H : $\hat{\Theta}$ is efficient under the null hypothesis $H_0 \rightarrow Cov\,(\hat{\Theta} - \bar{\Theta})$ =

=Var($\hat{\Theta}$)

In this study will be used only one explanatory variable X each time. In essence X as an economic factor, will be designated as real GDP per capita in most regression models implemented and as Road Quality Index in another. In this sense, in every regression model used will be evaded the possibility of involving endogenous X variables, therefore the Hausmann test will not be applied. In case of endogenous variables do exist in the regression model, the coefficients of the explanatory variable X are biased (i.e., incorrectly estimated). For instance, if are used 2 explanatory variables, Real GDP per capita and Road Quality index, the effect of one could be affect the effect of the other.

A second methodology to be pursued for data retrieved pertaining to a specific country; that is, Greece, is time series graphs presentation and discussion over the findings. Data from ELSTAT (Hellenic Statistical Authority) regarding the Real GDP of Greece over the period 1996-2019 are retrieved, and its respective road accidents, are presented in time series graphs individually, and all together as well. The elasticities of accidents and GDP will be analyzed and compared for the periods pertaining to the economic recession. The effect of economy during turbulent times will be highlighted and discussed.

Data are also retrieved by noted websites appertaining to high circulation newspapers in Greece such as *To Vima, Ta Nea* and inferences are drawn based on their reports. The gasoline prices in Greece in the long-run are also presented in a time series graph issued by *tradingeconomics.com*. The income elasticity of demand of fuels is another topic to be discussed according to the disposable data as a matter of income loss attributed to the decrease of GDP in absolute and per capita terms.

Chapter 4
Quantitative Results

4.1 Regression models for the EU state members

In the first part, cross-sectional data from Panel Data are collected for years 2010, 2018, 2019, each time, referring to EU state members and the OLS estimation method is used. Those years are chosen since sufficient data can be retrieved by Eurostat and European Commission regarding the real GDP per capita; that is, GDP per capita inflation adjusted, and traffic accidents fatality indicator. Real GDP per capita is considered a very significant and solid factor that indicates economic prosperity and high level of infrastructure in a particular economy (i.e. country) at a particular point of time (i.e. year).

Another indicator that could potentially be an indicator of high fatality rate caused by road traffic accident is the Roads Quality Index by European state member. A nation's progress in general is reflected on the transportation system with respect to the safe mobility of goods and people. The expansion of road transport network increases prosperity and wealth. (Tehreem, 2012) However, the expansion of the transportation network was linked to increase in road accidents. (Gulzar, Yahya, Mir, & Zafar, 2012) Countries with a world class quality road network might confront a smaller number per million habitants' fatalities. This will be identified by the utilization of OLS method in a regression model using this index as a regressor X and the number of fatalities per million habitants as a regressand Y.

Hypothesis test is also used in all paradigms to examine whether the coefficient b of the regressors is equal to zero, namely H_o: b = 0 (no linear relationship exists) and

H_1: b ≠ 0 (the coefficient of X_{it} is significant and linear relationship exists) for α = 0.05.

It is also examined if the R^2 is significantly different than zero, which is an indicator that a linear relationship exists and indicates what percent of explanatory variable(s) explain the regression linear equation. They are also examined the P-values of the regression models used and the respective of intercept and coefficients of the explanatory variable(s). P-values and t-tests are tested for a 95% significance on the models used, or else for α = 0.05.

On the first regression models for years 2010, 2018 and 2019 there are cross-sectional data of Real GDP per capita and Road fatalities per million inhabitants in all European Union countries except Malta. Malta has been excluded from the model, since transparent date could not be retrieved. Furthermore, we assume that the models are not affected from this exception, as Malta is a tiny island European Union state member with high population density and its location is considered rather remote from the other state members. In this report has not been included the ANOVA tables from Excel of the regression models applied, instead they are represented the tables from Eviews11. Since, in each case it has been designated a unique X regressor, the relevant linear and log-log regression models are drawn highlighting the R^2 and Regression Fitting Equations by MS Excel.

4.1.1 Real GDP per capita as the independent variable

The first linear regression model indicates the linear relationship between inflation and prices adjusted GDP per capita per country and theirs corresponding road accident fatalities indicator per million inhabitants:

Findings for EU state members in year 2010 applying Linear Regression Model 2nd and 3rd column of Table 1

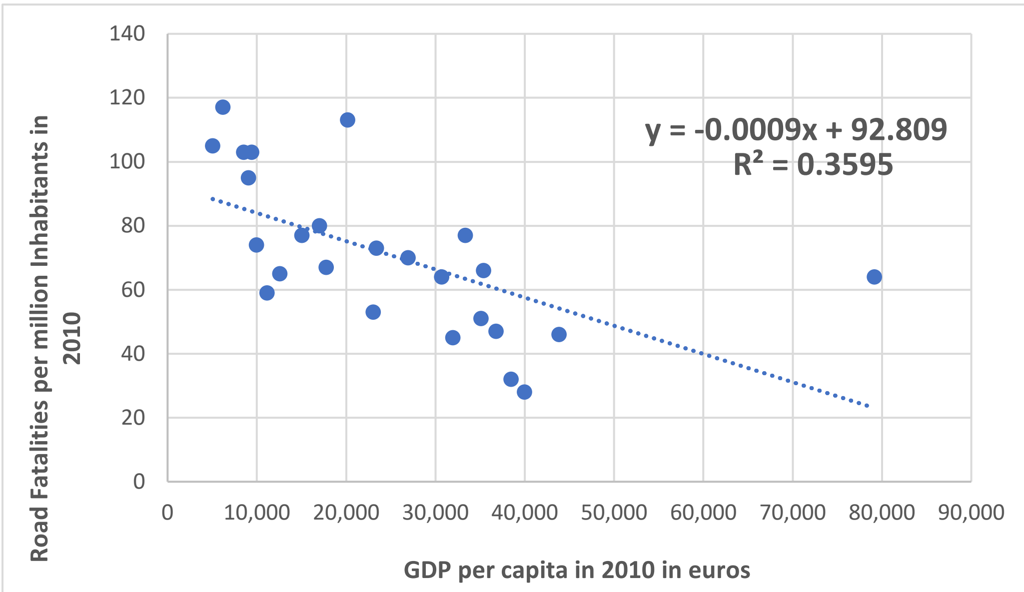

Figure 1. Linear regression model for 2010

Y = 92.81 - 0.0009*X

Y = Road Fatalities per million inhabitants in 2010

X = Real GDP per capita in 2010

Dependent Variable: FATALITIES_FROM_ACCIDENTS EU 2010
Method: Least Squares
Date: 04/12/21 Time: 12:01
Sample: 1 25
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	92.80869	7.260118	12.78336	0.0000
RealGDP per capita2010	-0.000881	0.000245	-3.592708	0.0015

R-squared	0.359466	Mean dependent var	70.96000
Adjusted R-squared	0.331617	S.D. dependent var	24.25297
S.E. of regression	19.82795	Akaike info criterion	8.888680
Sum squared resid	9042.391	Schwarz criterion	8.986190
Log likelihood	-109.1085	Hannan-Quinn criter.	8.915725
F-statistic	12.90755	Durbin-Watson stat	1.694124
Prob(F-statistic)	0.001537		

The Prob(F-statistic) = 0.0015, significantly lower than $\alpha = 0.05$, which indicates that the linear regression model used in this case is significant.

In this linear regression model, $r^2 = R^2 = SSR/SST = 0.36$,

r^2 = Simple Correlation Coeficient between Real GDP per capita and Road fatalities per million inhabitants, $0 \le r^2 \le 1$

R^2 = Coefficient of Determination, $0 \le R^2 \le 1$

SSR = Sum of Squares Explained by the Regression and

SST = Total Sum of Squares

In this model the 36% of variation of the dependent variable Y (Road fatalities) is explained by variation in X (Real GDP per capita) in 2010. Apparently, it easily can be proved conducting a Hypothesis Test that R^2 is significantly different from zero, therefore a correlation exists for the variables. The significance of F for the regression, intercept b_0 and coefficient b_1 of X_{it} are also examined. There are 3 ways of examination for the intercept and coefficient of the explanatory variable which are all included in the research. A t-test hypothesis test is used, where H_0: $b_1 = 0$ (no linear relationship exists) and H_1: $b_1 \neq 0$ (linear relationship does exist). The linear relationship given by the regression model is

Y = 92.809 - 0.0009*X

Road Fatalities per million inhabitants = 92.81 - 0.0009 * (GDP per capita)

In other words, ceteris paribus (all other parameters held constant) a country with a 10,000 more GDP per capita has 9 less deaths deriving from traffic accidents. Obviously, no EU state member has a GDP equal to 0, so $b_0 = 92.81$ just indicates that, for states within the range of GDP per capita observed, 92.81 is the portion of the state members not expained by GDP per capita.

Let's apply the regression equation to estimate the road fatalities in Italy.

$Y = 92.81 – 0.0009 * 26930 = 92.81 – 24.24 = 68.61 \approx 69$.

This estimation for Italy is very close to the observed amount of fatalities which is 70. In case of Italy, the corresponding point of estimation almost intercepts the line of Regression which is depicted by the above calculation.

Below is implemented the log-log regression model for the corresponding log-log transformed data so as to find a better estimation model with a higher value of R^2, that is; $R^2 > 0.36$, where $0 \leq R^2 \leq 1$.

Findings for EU state members in year 2010 applying the Log-Log Regression Model

In this model applied, all data collected; that is, those of depended Variable Y :Road fatalities per million inhabitants in year 2010 and of independent variable X : Real GDP per capita, are transformed in logarithmic mode.

In other words, they have been computed the ln values for each of the corresponding values of the initial model.

For instance in case of Italy, the road accident fatality indicator is 70 deaths per million inhabitants. Ln70 = 4.25

The corresponding Real GDP per capita is 26930. Ln26930 = 10.2.

This process has been pursued for all the EU state countries and the respective log-log linear Regression model is drawn:

Findings for EU state members in year 2010 applying Log-Log Regression Model

4th and 5th column of Table 1

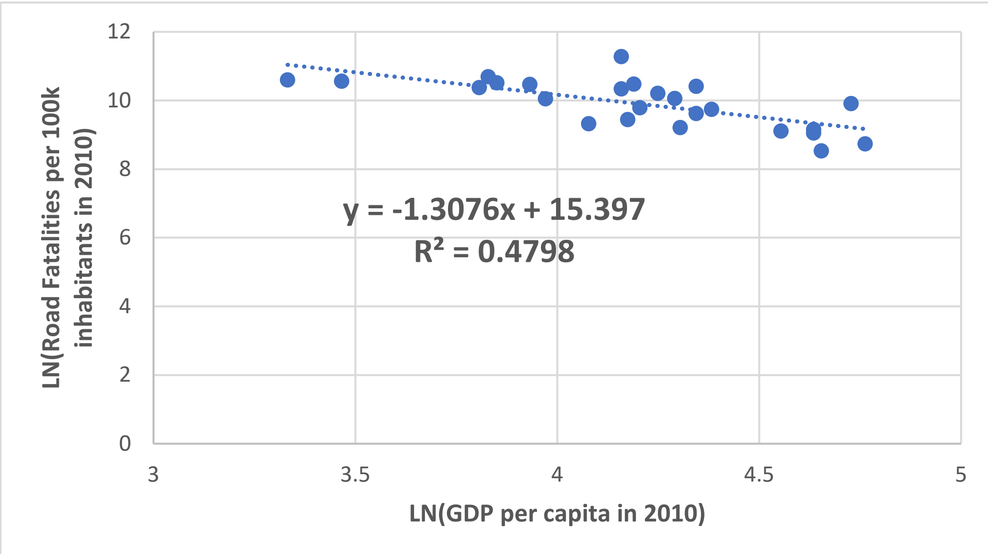

Figure 2.Log-Log transformed regression model for 2010

Y = 15.4 – 1.308*X

Y = ln(Road Fatalities per million inhabitants in 2010)

X = ln(Real GDP per capita in 2010)

Dependent Variable: LN (FATALITIES_FROM_ACCIDENTS EU 2010)
Method: Least Squares
Date: 04/12/21 Time: 12:19
Sample: 1 25
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	15.39664	1.197179	12.86077	0.0000
LN(Real GDP per capita 2010)	-1.307586	0.283920	-4.605475	0.0001

R-squared	0.479760	Mean dependent var	9.903263
Adjusted R-squared	0.457141	S.D. dependent var	0.694734
S.E. of regression	0.511873	Akaike info criterion	1.575137
Sum squared resid	6.026318	Schwarz criterion	1.672648
Log likelihood	-17.68922	Hannan-Quinn criter.	1.602183
F-statistic	21.21040	Durbin-Watson stat	2.492748
Prob(F-statistic)	0.000124		

In this log-log transformed regression model $R^2 = 0.48$ meaning that 48% of variation of LN(Y)=LN(Road fatalities) is explained by variation in LN(X)=LN(Real GDP per capita) in 2010. This is significantly higher than 36% found in the corresponding linear regression model. Consequently it can easily be proved that conducting a Hypothesis Test that R^2 is significantly different from zero, for $\alpha=0.05$, therefore a correlation does exist for the variables.

The significance of F for the regression, intercept b_0 and coefficient b_1 of X_{it} are also examined. A t-test hypothesis test is used, where H_0: $b_1 = 0$ (no linear relationship exists) and H_1: $b_1 \neq 0$ (linear relationship does exist). The F-statistic equals to 0.0001 which is significantly higher than $\alpha=0.05$. Therefore we can state with approximately 99.999% confidence that the log-log linear regression model applied is significant. The relationship given by the regression model is:

Y = 15.4 – 1.308*X

LN (Road Fatalities per million inhabitants) = 15.4 – 1.308 * LN(GDP per capita)

In other words, coeteris paribus (all other parameters held constant) a EU state member with 1 % more GDP per capita, experiences 1.3% less Road fatalities.

Let’s apply the findings of the model to estimate the road fatalities in Lithuania comparing with road fatalities in Latvia. GDP per capita in Lithuania = 9050, GDP per capita in Finland = 8520 in 2010.

9050 / 8520 = 1.062 which means that GDP in Lithuania is by 6.2% higher than in Latvia in year 2010. According to the log-log regression equation, the explanation is that in Lithuania we expect

6.2 * 1.3% = 8.06% less deaths from road accidents than in Latvia in 2010.
1 –8.06% = 91.94%
103 * 91.94% = 94.7 ≈ 95, which is precisily the observed amount of fatalities for Lithuania in 2010.

Indeed, in case of Lithuania and Latvia, applying the log-log regression model we estimate with 100% precision the amount of fatalities of one, coeteris paribus, given the amount of fatalities of the other country. The same model and respective explanations apply for the 2018 and 2019 data, in a similar manner.

Findings for EU state members in year 2018 applying Linear Regression Model 2nd and 3rd column of Table 2

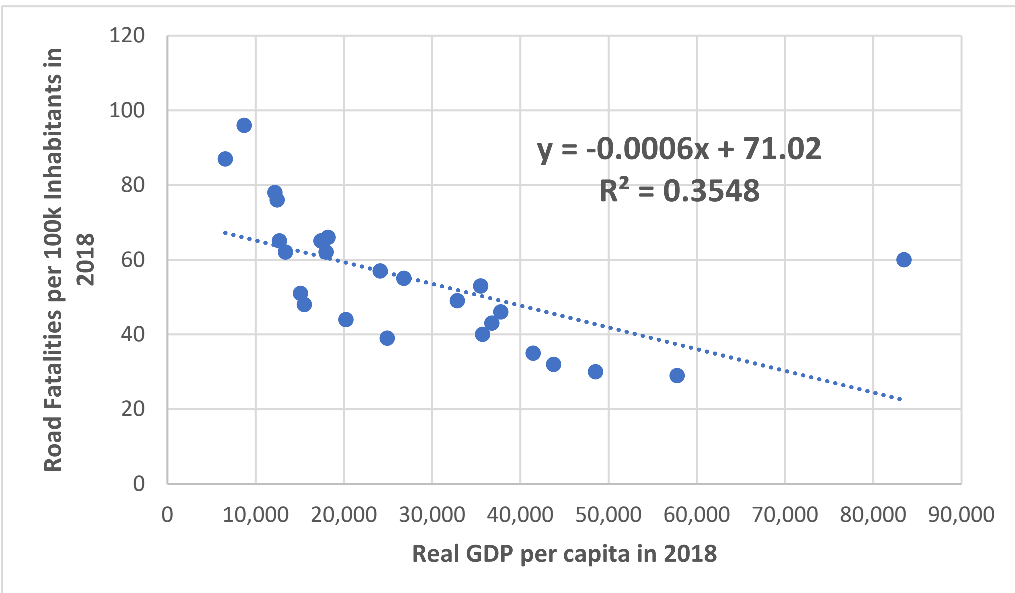

Figure 3.Linear regression model for 2018

Y = 71.02 - 0.0006*X

Y = Road Fatalities per million inhabitants in 2018

X = Real GDP per capita in 2018

Dependent Variable: FATALITIES_FROM_ACCIDENTS EU 2018

Method: Least Squares

Date: 04/12/21 Time: 14:39

Sample: 1 25

Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	71.02015	5.401886	13.14729	0.0000
Real GDP per capita 2018	-0.000582	0.000164	-3.556304	0.0017

R-squared	0.354790	Mean dependent var	54.72000
Adjusted R-squared	0.326737	S.D. dependent var	17.42010
S.E. of regression	14.29365	Akaike info criterion	8.234126
Sum squared resid	4699.092	Schwarz criterion	8.331636
Log likelihood	-100.9266	Hannan-Quinn criter.	8.261171
F-statistic	12.64730	Durbin-Watson stat	1.750491
Prob(F-statistic)	0.001680		

In 2018 the linear model gives significantly higher R^2 both in linear and log-log models comparing with the respective ones of 2010. The Prob(F-statistic) = 0.00168, significantly lower than $\alpha = 0.05$, which indicates that the linear regression model used in this case is significant. This could be also proved by the t-statistic (it is significant high in absolute value) for both C intercept and coefficient of Real GDP per capita in 2018. In this model the 36% of variation of the dependent variable Y (Road fatalities) is explained by variation in X_i(Real GDP per capita) in 2018.

Apparently, it can be proved easily conducting a Hypothesis Test that R^2 is significantly different from zero, therefore a correlation exists for the variables. The significance of F for the regression, intercept b_0 and coefficient b_1 of X are also examined. There are 3 ways of examination for the intercept and coefficient of the explanatory variable which are all included in the research. By application of t-test hypothesis test, where H_0: $b_1 = 0$ (no linear relationship exists) and H_1: $b_1 \neq 0$ (linear relationship does exist).

The linear relationship given by the regression model is

Y = 71.02 - 0.0006*X

Road Fatalities per million inhabitants in 2018 = 71.02 - 0.0006 * (Real GDP per capita in 2010)

In other words, coeteris paribus (all other constant) a country with a 10,000 more GDP per capita has 6 less deaths deriving from traffic accidents. Obviously, no EU state member has a GDP equal to 0, so b_0 = 71.81 just indicates that, for states within the range of GDP per capita observed, 71.81 is the portion of the state members not expained by GDP per capita.

Findings for EU state members in year 2018 applying Log-Log Regression Model

4th and 5th column of Table 2

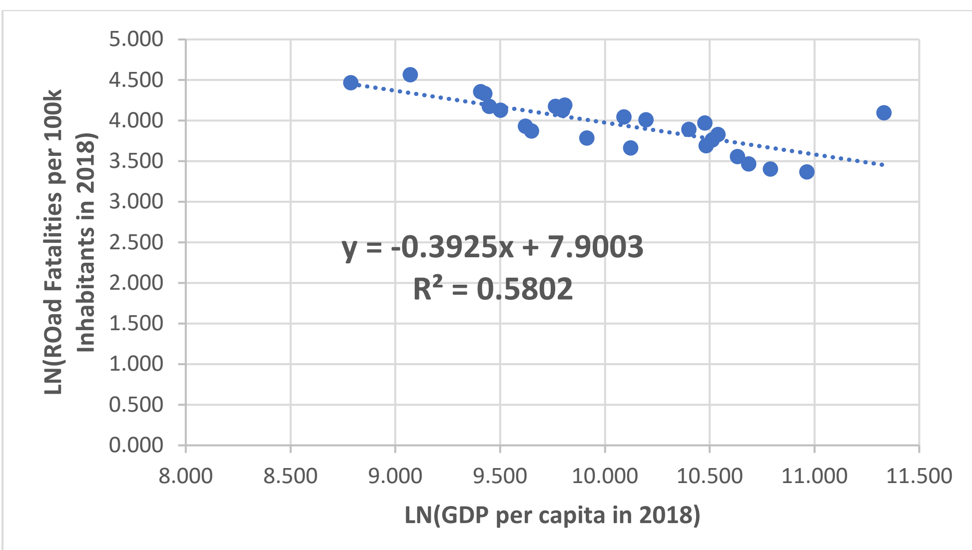

Figure 4.Log-Log transformed regression model for 2018

Y = 7.9 – 0.3925*X

Y = ln(Road Fatalities per million inhabitants in 2018)

X = ln(Real GDP per capita in 2018)

Dependent Variable: LN(FATALITIES_FROM_ACC. EU 2018)
Method: Least Squares
Date: 04/12/21 Time: 15:00
Sample: 1 25
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.900340	0.701388	11.26387	0.0000
LN (Real GDP per capita 2018)	-0.392450	0.069613	-5.637625	0.0000

R-squared	0.580160	Mean dependent var	3.953453
Adjusted R-squared	0.561906	S.D. dependent var	0.321244
S.E. of regression	0.212627	Akaike info criterion	-0.181934
Sum squared resid	1.039837	Schwarz criterion	-0.084424
Log likelihood	4.274180	Hannan-Quinn criter.	-0.154889
F-statistic	31.78281	Durbin-Watson stat	1.816772
Prob(F-statistic)	0.000010		

Y = 7.9 – 0.3925*X

LN (Road Fatalities per million inhabitants in 2018) = 7.9 – 0.3925 * LN(GDP per capita in 2018)

In ceteris paribus terms, it can be stated that for year 2018, a 1% increase in Real GDP per capita, leads to 0.39% decrease in Road Fatalities among different EU state member countries.

This appears to be significantly smaller than 1.3% incremental change in year 2010. It can be derived that after a period of 8 years the impact of economy is lower than previously.

Findings for EU state members in year 2019 applying Linear Regression Model 2nd and 3rd column of Table 3

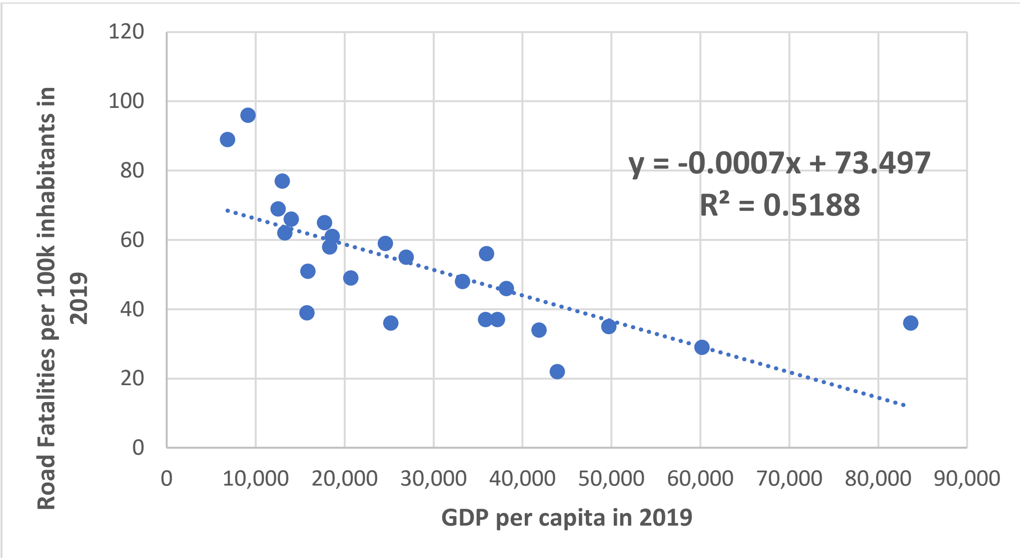

Figure 5.Linear regression model for 2019

Y = 73.5 - 0.0007*X

Y = Road Fatalities per million inhabitants in 2019

X = Real GDP per capita in 2019

Dependent Variable: FATALITIES_FROM_ACC. EU 2019
Method: Least Squares
Date: 04/12/21 Time: 18:20
Sample: 1 25
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	73.49709	4.959599	14.81916	0.0000
Real GDP per capita 2019	-0.000738	0.000148	-4.979420	0.0000

R-squared	0.518774	Mean dependent var	52.48000
Adjusted R-squared	0.497852	S.D. dependent var	18.37598
S.E. of regression	13.02167	Akaike info criterion	8.047725
Sum squared resid	3899.968	Schwarz criterion	8.145235
Log likelihood	-98.59656	Hannan-Quinn criter.	8.074770
F-statistic	24.79463	Durbin-Watson stat	1.597540
Prob(F-statistic)	0.000049		

Findings for EU state members in year 2019 applying Log-Log Transformed Regression Model

4th and 5th column of Table 3

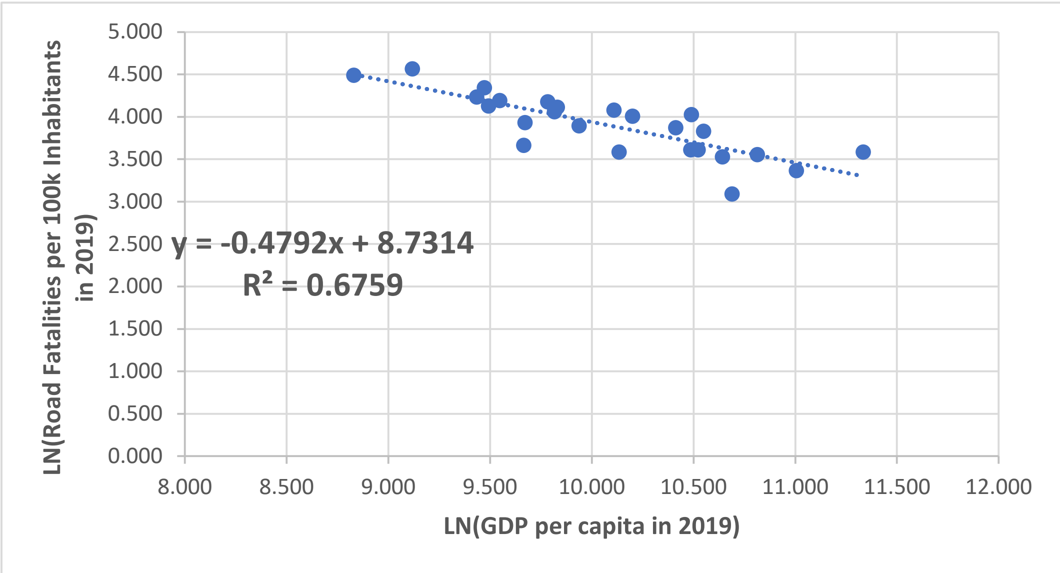

Figure 6.Log-Log transformed regression model for 2019

Y = 8.73 - 0.48*X

Y = ln(Road Fatalities per million inhabitants in 2019)

X = ln(Real GDP per capita in 2019)

Dependent Variable: LN(FATALITIES_FROM_ACC. EU 2019)
Method: Least Squares
Date: 04/12/21 Time: 18:31
Sample: 1 25
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.731395	0.698730	12.49609	0.0000
LN (Real GDP per capita 2019)	-0.479242	0.069198	-6.925674	0.0000

R-squared	0.675896	Mean dependent var	3.900783
Adjusted R-squared	0.661805	S.D. dependent var	0.357253
S.E. of regression	0.207759	Akaike info criterion	-0.228261
Sum squared resid	0.992764	Schwarz criterion	-0.130751
Log likelihood	4.853265	Hannan-Quinn criter.	-0.201216
F-statistic	47.96496	Durbin-Watson stat	1.353634
Prob(F-statistic)	0.000000		

The findings of the 6 linear and log-log Regression models applied for the years 2010,2018 and 2019 share some similar quantitative characteristics:

- Probability of the intercept C ≈ 0 with α=0.05 which indicates that the intercept is significant in all models used
- Probability of the coefficient of the independent variable X ≈ 0, therefore it is significant for α=0.05
- Prob(F-stat) = 0 which indicates that the models used are significant with α=0.05
- DW test for linear regression models are equal to 1.7, 1.75 and 1.6 for years 2010, 2018 and 2019 respectively which means that $1.6 \leq DW \leq 2.4$ (empirical rule) and implies that autocorrelation does not exist.

4.1.2 Road Quality Index as the independent variable

Risky driving could be classified into various subcategories. The core factors that might lead to risky driving is drunk driving, drug-impaired driving, when the driver is prescribed with drugs and medication, driving a vehicle being drowsy. Moreover, the omitting of seat belts usage (Transportation, 2021) is another key factor that leads to risky driving.

Some main human factors considered are the visibility and hearing capacity of the driver, the consumption of alcoholic beverages, the prescription of drugs for medical purposes, or for personal satisfaction. Concerning the medical factors that may deteriorate driving capacity of a driver are a vast range of neurological disorders, psychiatric disorders, mental disorders, cardiovascular long-term diseases and some metabolic disorders such as diabetes. (Vasilakakos, και συν., 1999)

Risk factors could be also ascribed to the operating environment. Some of them are weather conditions, the situation of the pavement, the night-time or day-time driving, the existence and efficacy of sufficient illumination. Moreover, adequacy of road markings and the traffic conditions also contribute in the possibility of occurrence of a road accident. (Beeck, Borsboom, & Mackenbach, 2000)

Although the quality of the pavement, or in general the quality of road network of a country is not the leading factor of traffic accidents occurrence, it could be considered, implicitly, a factor stemming from Economy. (Tehreem, 2012)The infrastructure level of a country in most cases is reflected by the overall economic situation of a country. High quality infrastructure is traced mainly in the developed-world and it considered an indicator of prosperity and well-being for citizens. (Beeck, Borsboom, & Mackenbach, 2000)

A survey by the World Economic Forum, rating the road quality infrastructure using a scale from 1 (extremely poor, among the worst in the world) to 7 (extremely good, among the best in the world) is represented by the World Economic Forum Global Competitiveness Report. The figures are shown analytically in the appendix. (Union, 2018)

Findings for EU state members in year 2018 applying a Linear Regression Model for Road Quality Index

2nd and 3rd column of Table 4

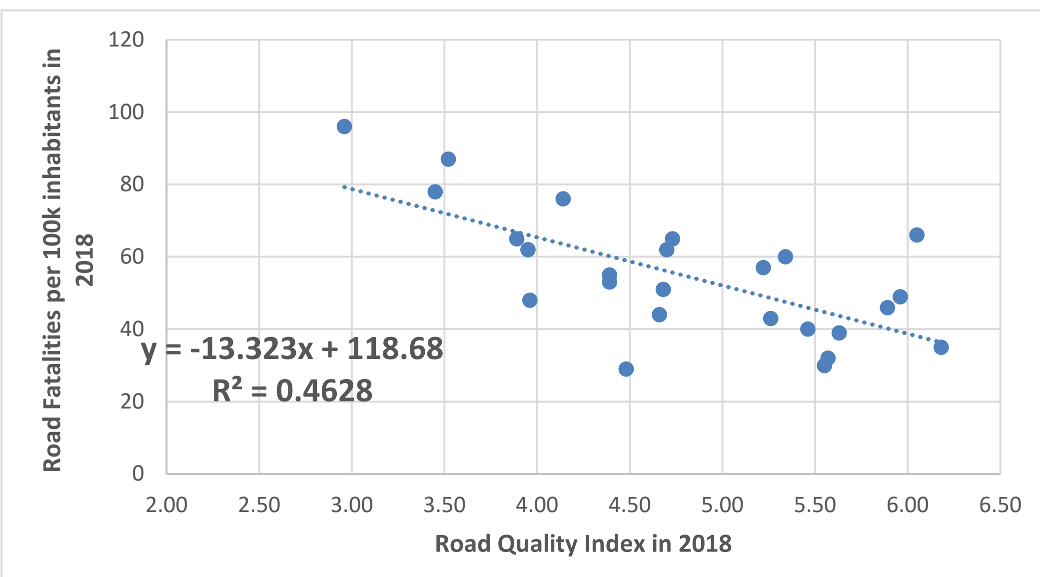

Figure 7.Linear regression model for road quality index in 2018

Y = 118.68 – 13.323*X

Y = Road Fatalities per million inhabitants in 2018

X = Road Quality Index in 2018

Dependent Variable: Road Fatalities per million inhabitants in 2018
Method: Least Squares
Date: 04/12/21 Time: 20:39
Sample: 1 25
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	118.6778	14.60434	8.126202	0.0000
ROADS_QUALITY_2018	-13.32343	2.993391	-4.450948	0.0002

R-squared	0.462754	Mean dependent var	54.72000
Adjusted R-squared	0.439396	S.D. dependent var	17.42010
S.E. of regression	13.04304	Akaike info criterion	8.051005
Sum squared resid	3912.783	Schwarz criterion	8.148516
Log likelihood	-98.63757	Hannan-Quinn criter.	8.078051
F-statistic	19.81094	Durbin-Watson stat	1.487450
Prob(F-statistic)	0.000183		

According to the linear regression model applied, a negative linear relationship does exist between Road fatality per million inhabitants index and road quality index in year 2018. The relationship is negative, since the estimated coefficient of X is -13.32.

Under the ceteris paribus assumption, a country having being rated by 1 more unit for its road network, appears to have approximately 13 less fatality index per million inhabitants. Let's apply this find for two countries having almost 1 unit difference concerning their road quality index. The fatality index of Germany is 40 and the corresponding road quality index is 5.46. On the other hand the fatality index of Belgium is 53 and the respective road quality index is 4.39.

Without numerical application on the estimated regression model, it is apparent that Germany which have a better road network than Belgium by 1.07 points, appears to have 13 less demises per million inhabitants. This finding is quite sensible, since driving in world-class Road network is rather safe for its users. Due to urbanization, in the developed world, the citizens do afford the acquisition of high quality vehicles(of higher passive and active safety standards) ,the medical facilities are of hgher standards and the law enforcement is applied more efficiently.

R^2 = 0.46 indicates that 46% of variation of Y (Road fatalities) is explained by variation in X(Road Quality Index) in 2018. It is proved conducting a Hypothesis Test that R^2 is significantly different from zero, therefore a linear relation does exist for the variables X and Y. The significance of F for the regression, intercept b_0 and coefficient b_1 of X are also examined. A t-test hypothesis test is used, where H_0: b_1 = 0 (no linear relationship exists) and H_1: $b_1 \neq 0$ (linear relationship does exist). The relationship given by the regression model as stated previously is;

Y = 118.68 – 13.323X

(Road Fatalities per million inhabitants) = 118.68 - 13.32 * (Road Quality Index)

Obviously, no EU state member has been rated with a Road Fatality Index equal to 0, so b_0 = 118.68 indicates that, for states within the range of Road Quality Index observed, 118.68 is the portion of the state members not expained by Road Quality Index.

Let's apply the estimated regression equation to estimate the road fatalities in Hungary.

Y = 118.68 – 13.32 * 3.89 = 66.87 ≈ 67.

This estimation of deaths for Hungary is relatively close to the actual amount of fatalities which is 65. This is apparent on the above scatter diagram, that is; the point representing Hungary is that with Coordinates (3.89, 66.87) which lies relatively close to the line of the Regression model used. Portugal seems to be an outlier point.
Portugal has the 2nd higher Road Quality Index with 6.05 points, just after the Netherlands with 6.18. Portugal has a relatively high number of road traffic fatalities somewhere near the mean, which itself indicates a rather careless driving behaviour

which could be attributed to other, more explicit, economic factors, such as real GDP per capita which is relatively low. The paradox found in case of Portugal is that it is a state with a low GDP per capita, appears to have been rated with a high road index rate.

4.2 Regression models in global scale

In this second part, cross-sectional data from panel data are collected for current estimated values for all those nations for whom reliable and sufficient data are provided by the IMF and WHO. In this case real GDP per capita in $; that is, inflation adjusted, is actually equal to nominal GDP per capita, since inflation adjustment is computed and regarded in the long-term, not for a certain year. The IMF provides current annual estimates for all countries globally (October 2020), whereas, the WHO does not provide sufficient road fatality data for each country. The model is applied for those countries for whom available data are retrieved both by WHO and IMF. The data collected are considered reliable, and the fact that some (in most cases small, island, third-world countries) are omitted, we assume that does not affect the OLS estimation.

In this section, will be examined and identified, if any, nexus between the GDP per capita, which is considered the regressor X and the independent variable Y; that is, road fatalities per million inhabitants, does exist. The research in global scale could be divided in two subsections. The first one will be the utilization of OLS method for all countries. The second part pertains to the subdivision of those countries into two categories: rich and poor nations. This subdivision might facilitate the derivation of significant findings and inferences concerning the driving behaviour and mentality of poor and rich nation’s inhabitants respectively.

However, the majority of rich nations are actually European countries, which have already been included in the previous OLS estimations. Those finding have already given sufficient explanation for the negative linear relationship between road traffic accidents and prosperity.

Findings in global scale based on current estimations applying Linear Regression Model

2nd and 3rd column of Table 5

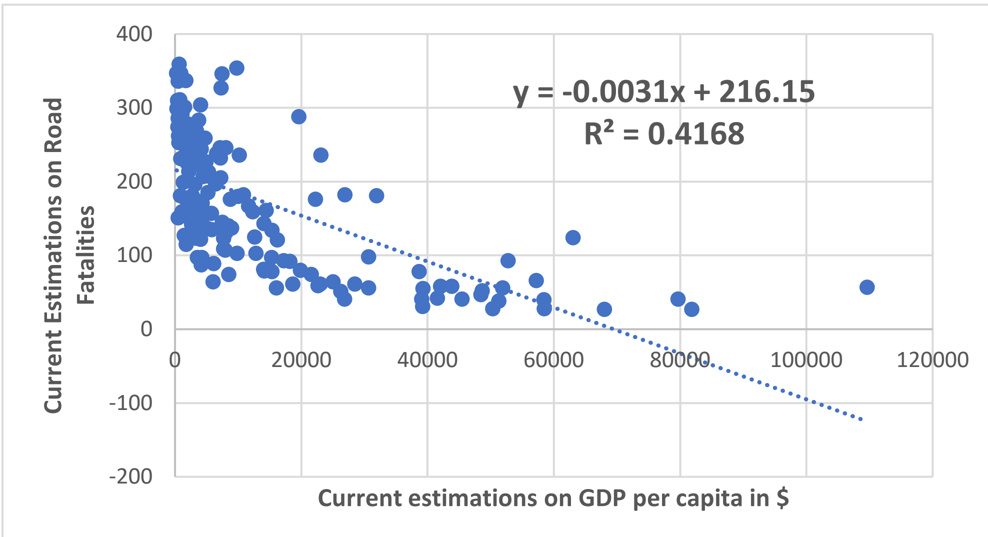

Figure 8.Linear regression model based on estimations in global scale

Y = 216.15 - 0.0031*X

Y = Road Fatalities per million inhabitants (current estimations)

X = GDP per capita (current estimations)

Dependent Variable: FATALITIES__WHO__ESTIMATES
Method: Least Squares
Date: 04/14/21 Time: 13:15
Sample: 1 163
Included observations: 163

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	216.1532	6.756035	31.99409	0.0000
GDP_PER_CAPITA__IMF__2020_ESTIMATES	-0.003112	0.000290	-10.72720	0.0000

R-squared	0.416821	Mean dependent var	173.6748
Adjusted R-squared	0.413198	S.D. dependent var	91.23128
S.E. of regression	69.88588	Akaike info criterion	11.34380
Sum squared resid	786329.8	Schwarz criterion	11.38176
Log likelihood	-922.5196	Hannan-Quinn criter.	11.35921
F-statistic	115.0729	Durbin-Watson stat	1.516398
Prob(F-statistic)	0.000000		

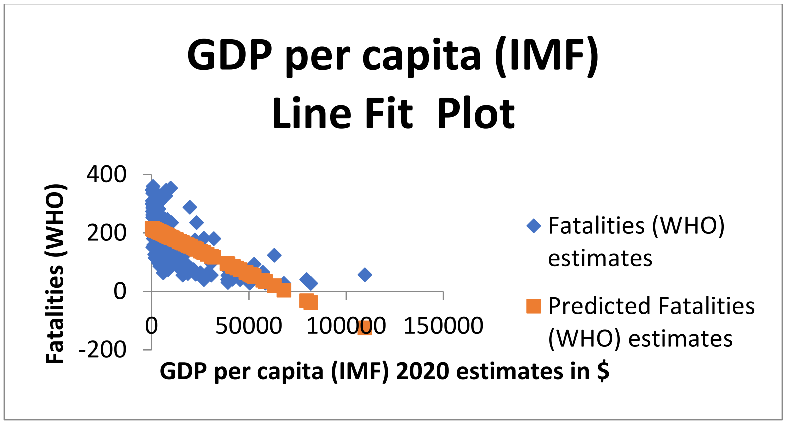

Figure 9.Line Fit Plot of the linear regression model

R^2 = 0.42 which means that 42% of variation of Y (Road fatalities) is explained by variation in X(Road Quality Index). It is proved conducting a Hypothesis Test that R^2 is significantly different from zero, therefore a correlation exists for the variables. The significance of F for the regression, intercept and coefficient of X are also examined. Under t-test hypothesis tests, where H_0: b = 0 (no linear relationship exists) and H_1: b ≠ 0 (linear relationship does exist), we reject the null hypothesis, since the Probability of the t-test of the coefficient b is equal to 0 under α=0.05. In other words for α=0.05 a linear relationship does exist. Therefore, the relationship drawn by the regression model is:

Y = 216.15 – 0.0031X

(Road Fatalities per million inhabitants) = 216.15 – 0.0031 * (GDP per capita in $)

In other words, ceteris paribus (all other kept constant) a country with a higher GDP per capita by 1000 dollars has approximately 3 less deaths deriving from traffic accidents. Obviously, no country has a GDP per capita equal to 0, so b_0 = 216.15 indicates that, for countries within the range of GDP per capita observed, 216.15 is the portion of the state members not expained by GDP per capita.

Let's apply the regression equation to estimate the road fatalities in Russia.

Y = 216.15 – 0.0031 * 9972 = 216.15 – 30.91 = 185.24 ≈ 185

The actual number of fatalities caused by traffic accidents in Russia is 180. In the above Scatter Diagram the point representing Russia apparently lies relatively close to the regression model fitting line. It is apparent from the Scatter Diagram that there is a stronger negative relationship for low and very low income countries than in medium and high-income countries. For GDP per capita less than 10,000 dollars per year the corresponding fitting line would have been "steeper" indicating a stronger negative relationship between GDP per capita and traffic accidents fatalities.

Specifications Tests

a) Correct, model specification:

Linearity, Ramsey's Reset Test

H_0 : relationship is linear

H_1 : relatonship is nonlinear

The core idea is to test the joint significance of additional regressors

A hypothesis test is contucted:

Null Hypothesis: $H_0 : \gamma = 0$

Alternative Hypothesis: $H_1 : \gamma \neq 0$

Applying a Ramsey's RESET test occurs the following table:

Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Squares of fitted values
Specification: FATALITIES__WHO__ESTIMATES C GDP_PER_CAPITA__I
MF__2020_ESTIMATES

	Value	df	Probability
t-statistic	5.815775	160	0.0000
F-statistic	33.82324	(1, 160)	0.0000
Likelihood ratio	31.25897	1	0.0000

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	137218.9	1	137218.9
Restricted SSR	786329.8	161	4884.036
Unrestricted SSR	649110.8	160	4056.943

LR test summary:

	Value
Restricted LogL	-922.5196
Unrestricted LogL	-906.8901

Unrestricted Test Equation:
Dependent Variable: FATALITIES__WHO__ESTIMATES
Method: Least Squares
Date: 04/15/21 Time: 12:06
Sample: 1 163
Included observations: 163

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-16.56525	40.48602	-0.409160	0.6830
GDP_PER_CAPITA__IMF__2020_ESTIM...	0.000578	0.000687	0.840528	0.4019
FITTED^2	0.005425	0.000933	5.815775	0.0000

R-squared	0.518589	Mean dependent var	173.6748
Adjusted R-squared	0.512571	S.D. dependent var	91.23128
S.E. of regression	63.69413	Akaike info criterion	11.16430
Sum squared resid	649110.8	Schwarz criterion	11.22124
Log likelihood	-906.8901	Hannan-Quinn criter.	11.18741
F-statistic	86.17807	Durbin-Watson stat	1.820094
Prob(F-statistic)	0.000000		

The probability of t-stat of of Fitted^2 is equal to zero. This implies that the newly introduced coefficient γ of Y^2 is significant for α = 0.05.

We reject the null hypothesis that $\gamma = 0$ and for α = 0.05 we accept the alternative hypothesis that $\gamma \neq 0$.

There are signs of misspecification of the model selected, particularly there is enough evidence that there is nonlinearity in the data.

b) No autocorrelation

autocorrelation, Durbin-Watson Test

H_0 : no autocorrelation

H_1 : positive or negative autocorrelation

For Durbin-Watson test always is valid that $0 \leq DW \leq 4$

If $0 \leq DW < 2$ positive autocorrelation exists

If $DW = 2$ no autocorrelation exists

If $2 < DW \leq 4$ negative autocorrelation exists

In this case DW = 1.52, not significantly smaller than 2, but which indicates positive autocorrelation. Consequently, we could state that the OLS estimator is unbiased but not efficient any more.

c) Homoscedasticity

White-Test

H_0 : homoskedasticity exists

H_1 : heteroskedasticity exists

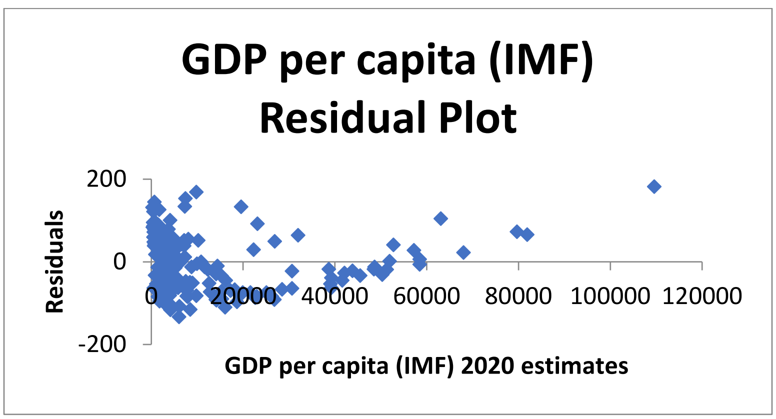

Figure 10.Residual Plot of the linear regression model

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	10.19262	Prob. F(2,160)	0.0001
Obs*R-squared	18.42054	Prob. Chi-Square(2)	0.0001
Scaled explained SS	11.32780	Prob. Chi-Square(2)	0.0035

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/15/21 Time: 12:45
Sample: 1 163
Included observations: 163

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6012.251	575.4160	10.44853	0.0000
GDP_PER_CAPITA__IMF__2020_ESTIM...	3.29E-06	7.30E-07	4.499020	0.0000
GDP_PER_CAPITA__IMF__2020_ESTIM...	-0.217590	0.054530	-3.990284	0.0001

R-squared	0.113009	Mean dependent var	4824.109
Adjusted R-squared	0.101922	S.D. dependent var	5433.151
S.E. of regression	5148.833	Akaike info criterion	19.94916
Sum squared resid	4.24E+09	Schwarz criterion	20.00610
Log likelihood	-1622.857	Hannan-Quinn criter.	19.97228
F-statistic	10.19262	Durbin-Watson stat	1.575906
Prob(F-statistic)	0.000068		

The prob. Chi-Square(2) = 0.0001 < 0.05 = α

Therefore, we can reject the null hypothesis with almost 100% confidence.

We accept the alternative hypothesis that heteroscedasticity does exist.

This is also evident by the preceding Residual plot.

d) Distributional assumptions

Jarque-Bera Test

H_0 : normal distribution

H_1 : non normal distribution

JB = $\frac{N-K}{6} * (S^2 + \frac{(K-3)2}{4}) \backsim X_z^2$

The null hypothesis H_0 is rejected if JB > 6 for α = 0.05

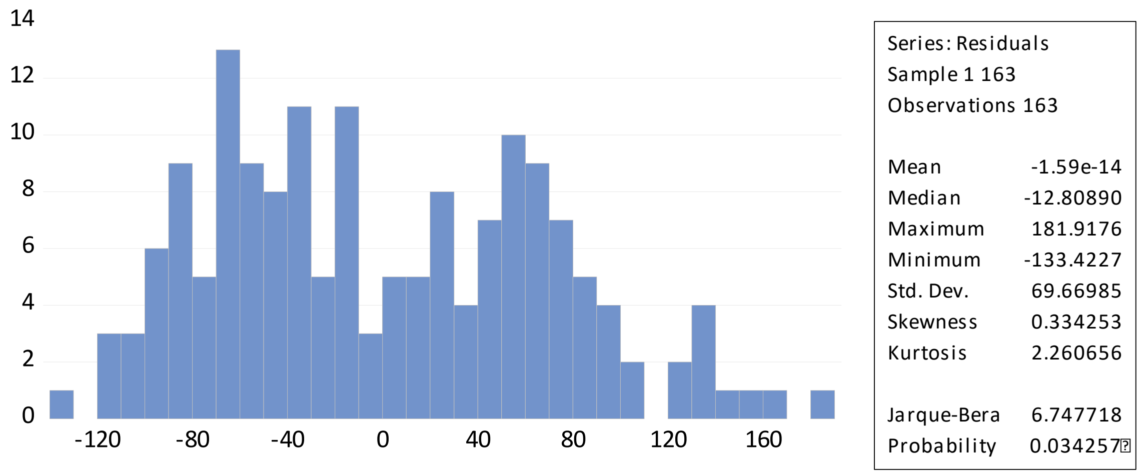

Figure 11.Distribution of the linear regression model

There are two ways to conduct the Jarque-Bera Test:

- Prob of JB = 0.034 < 0.05 = α, therefore we reject the null hypothesis
- JB = 6.75 > 6, therefore for α = 0.05 we reject the null hypothesis

We accept the alternative hypothesis that the distribution is not linear.

Findings in global scale based on current estimations applying Transformed Log-log Regression Model

4th and 5th column of Table 5

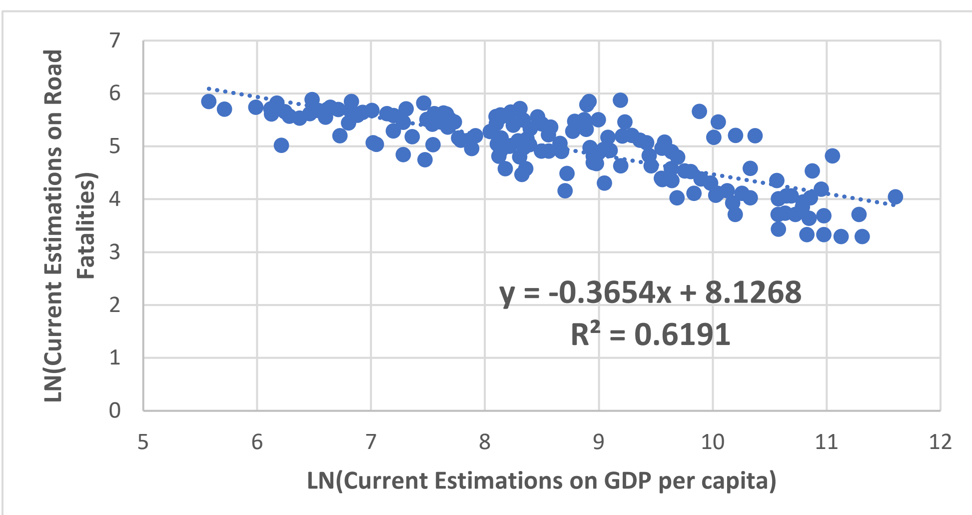

Figure 12.Log-Log transformed regression model based on estimation in a global scale

Y = 8.13 - 0.365*X

Y = Ln_Road Fatalities per million inhabitants (current estimations)

X = Ln_GDP per capita (current estimations)

Dependent Variable: LN_FATALITIES_WHO_ESTIMATES_
Method: Least Squares
Date: 04/15/21 Time: 13:58
Sample: 1 163
Included observations: 163

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.126769	0.197434	41.16197	0.0000
LN_GDP_PER_CAPITA_ESTIMATES_	-0.365434	0.022588	-16.17813	0.0000

R-squared	0.619144	Mean dependent var	4.975204
Adjusted R-squared	0.616778	S.D. dependent var	0.662392
S.E. of regression	0.410053	Akaike info criterion	1.067133
Sum squared resid	27.07110	Schwarz criterion	1.105094
Log likelihood	-84.97138	Hannan-Quinn criter.	1.082545
F-statistic	261.7319	Durbin-Watson stat	1.874619
Prob(F-statistic)	0.000000		

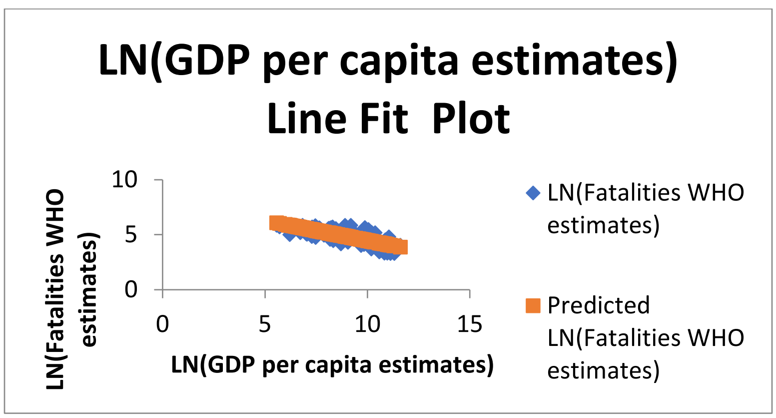

Figure 13.Line Fit Plot of the Log-log regression model

R^2 = 0.62 meaning that 62% of variation of LN(Y), LN(Road fatalities) is explained by variation in LN(X_{it}), LN(GDP per capita) based on current estimations of IMF. This is significantly better fit than 42% found in the corresponding linear regression model. It is proved conducting a Hypothesis Test that R^2 is significantly different from zero, therefore a correlation exists for the variables.

The significance of F for the regression, intercept b_0 and coefficient b_1 of X are also examined. A t-test hypothesis test is used, where H_0: $b_1 = 0$ (no linear relationship exists) and H_1: $b_1 \neq 0$ (linear relationship for the log-log transformed data does exist). The relationship given by the regression model is:

Y = 8.13 - 0.365X

LN (Road Fatalities per million inhabitants) = 8.13 ─ 0.37 * LN(GDP per capita)

In other words, ceteris paribus (all other parameters kept constant) a richer nation by 10 % more GDP per capita, experiences 3.7% less Traffic accident fatalities per million inhabitants.

Let's apply the findings of the model to estimate the road fatalities in Iceland comparing with road fatalities in New Zealand. GDP per capita in New Zealand = 38675 dollars, GDP per capita in Iceland = 57189.

57189 / 38675 = 1.4789 which means that GDP in Iceland is by 47.87% higher than in New Zealand based on current estimations of IMF.

According to the log-log equation, the explanation is that in Iceland we expect 47.87% * 0.37 = 17.71% less deaths from road accidents than in New Zealand.

1 – 17.71% = 82.29%

78 * 82.29% = 64.19 ≈ 64, which is close to the observed amount of fatalities for Iceland 66.

All in all, the above regression models indicate, that a negative linear relationship between GDP per capita, that is; the average output of a citizen of one country at a specific year, and number of traffic accidents in that specific country and year, does exist. The elesticities, between the two aforementioned variables, deriving in each case from the log-log transformed regression models will be discussed and compared in the next chapter.

Specifications Tests

a) **Correct, model specification:**

Linearity, Ramsey's Reset Test

H_0 : relationship is linear

H_1 : relatonship is nonlinear

$y_i = \beta_i + \beta_2 * x_2 + \beta_3 * x_3 + ... + \beta_k * x_k + \varepsilon_i$, $i = 1,..., n$

adding the variable $\hat{y}_i^2$ to the linear regression model occurs:

$y_i = \beta_i + \beta_2 * x_2 + \beta_3 * x_3 + ... + \beta_k * x_k + \gamma * \hat{y}_i^2 + \varepsilon_i$, $i = 1,..., n$

A hypothesis test is contucted:

Null Hypothesis: $H_0 : \gamma = 0$

Alternative Hypothesis: $H_1 : \gamma \neq 0$

Applying a Ramsey's RESET from **Table 8** we derive:

LR = - 84.97, the t-stat of Fitted^2 = - 4.76 F stat and its respective probability equals to 0 < 0.05, therefore the coefficient is significant for $\alpha = 0.05$ and we reject the null hypothesis that $\gamma = 0$ and do accept the alternative hypothesis that $\gamma \neq 0$.

There are signs of misspecification of the model selected, particularly there is enough evidence that there is nonlinearity in the data.

b) **No autocorrelation**

autocorrelation, Durbin-Watson Test

H_0 : no autocorrelation

H_1 : positive or negative autocorrelation

For Durbin-Watson test always is valid that $0 \leq DW \leq 4$

If $0 \leq DW < 2$ positive autocorrelation exists

If $DW = 2$ no autocorrelation exists

If $2 < DW \leq 4$ negative autocorrelation exists

In this case DW = 1.87, not significantly smaller than 2.

Empirically if $1.6 \leq DW \leq 2.4$ we accept that no autocorrelation exists.

c) Homoscedasticity

White-Test

H_0 : homoskedasticity exists

H_1 : heteroskedasticity exists

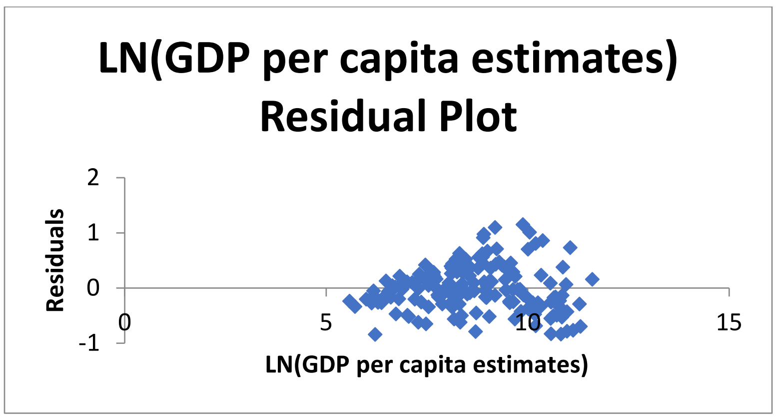

Figure 14.Residual Plot of the Log-Log regression model

From the Residual Plot, it is apparent that heteroscedasticity does exist.

Conducting a White-Test from **Table 9** occurs:

The prob. Chi-Square(2) = $0.0006 < 0.05 = \alpha$

Therefore, we can reject the null hypothesis with almost 100% confidence.

We accept the alternative hypothesis that heteroscedasticity does exist. As it is apparent from the Residual Plot above, the error terms are not normally dispersed for the high income nations.

d) Distributional assumptions

Jarque-Bera Test

H_0 : normal distribution

H_1 : non normal distribution

JB = $\frac{N-K}{6} * (S^2 + \frac{(K-3)2}{4}) \backsim X_z^2$

The null hypothesis H_0 is rejected if JB > 6 for α = 0.05

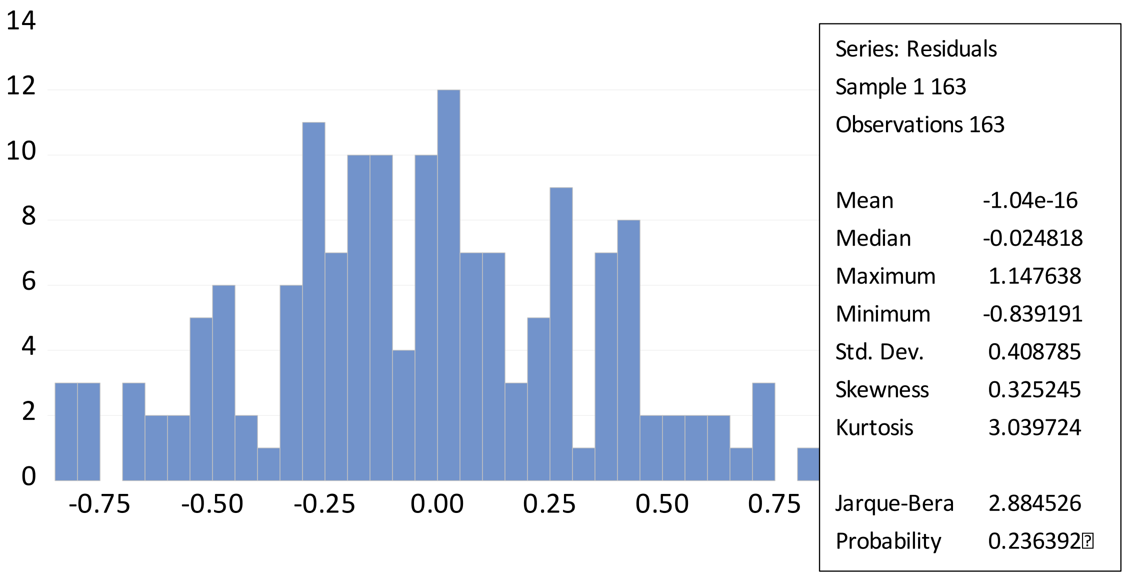

Figure 15.Distribution of the Log-Log regression model

Apparently, the shape of the distribution looks like a bell-shaped distribution and it is very likely to prove that the distribution is normal for α = 0.05.

There are two ways to conduct the Jarque-Bera Test:

- Prob of JB = 0.24 > 0.05 = α, therefore we cannot reject the null hypothesis
- JB = 2.88 < 6, therefore for α = 0.05 we cannot reject the null hypothesis

We have enough evidence to accept the null hypothesis that the distribution is normal.

4.3 Time series for Greece

In the third part, data for Greece are retrieved and presented in time series concerning the Real GDP per capita and the road accident fatality indicators. The extent to which traffic accident fatalities are associated with an extended decline of GDP per capita will be investigated. For that purpose, the ideal selection of country appeared to be Greece.

The global financial crisis outbroke in European countries as a dept crisis (or sovereign dept crisis) since the end of 2009. During that period, the most afflicted European countries, which proved to be uncapable to repay their government dept, were Greece, Portugal, Spain, Ireland and Cyprus. This incapability of repaying their depts or bailing out them over-indebted financial institutions under their national supervision, without any external assistance.

Greece is the unique European Union state member that incurred a constant and steep decline of its Real GDP (inflation adjusted) during the global financial crisis. In the next two time series graphs, this steep decline is dipicted as compared to the European Union decline (or growth in some particular years). In the first time series graph, data from the Official Hellenic Statistic Department; that is, ELSTAT: Hellenic Statistical Authority, are collected and placed all together from year 1996 to 2019.

Based on Table 7

Figure 16.Time series Real GDP in million euros

By the graph can be highlighted the constant economic growth which Greece experience before the outbreak of crisis, more specifically, in the period 1996-2008. Globalization, factorization, the adoption of the common European currency; that is, euro, international agreements, and formation of highly competitive markets facilitated the creation of a field of prosperity and well-being for the European Union countries. The unification and integration of the transportation system, accomplished by the construction of world class highways interconnecting countries one with another, also contributed in the circulation of people, goods and top-class services, all of which resulted to formation of economies of scale.

In the following graph, data from the World Bank are collected regarding the yearly elasticity of GDP in Greece and in the European Union respectively, for the period of 1996-2019. The time series graph suggests that Greece is soundly affected by the global financial crisis which outbroke in the European continent in 2019.

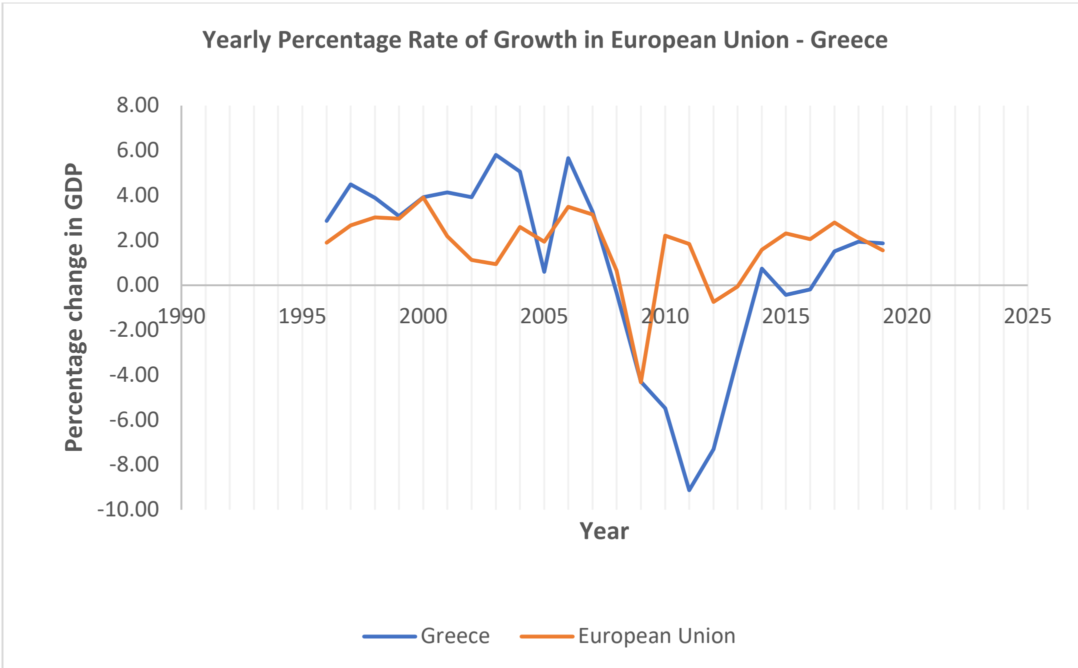

Figure 17.Comparative annual change in GDP (EU- Greece)

source: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2019&locations=EU-GR&start=1996&view=chart

To make matters clear, the blue line, representing Greece lies constantly below the corresponding orange line, representing the EU average of yearly economic growth. Greece constitutes has a population of 10.7 million inhabitants as per 2018 as opposed to 512.6 million of European Union in the same year. That practically means that Greece constitutes only the 2.08% of the European Union total population. That is translated to 2.08% total GDP per capita within the EU. However, its relatively small size in GDP terms, during the period of 2009-2018, contributed negatively in the average GDP of EU in number terms.

The paradox is that particularly in 2011, the EU experiences an economic growth of 1.83%, whereas Greece reaches its negative "peak", the lowest point with an annual growth rate of -9.13%. This implies that during the third year of crisis, the prosperous and less prosperous country members had the mechanisms to reply to the crisis, however Greece sunk its production output, investment, private and governmental spending. If Greece had maintained its GDP as its 2010 corresponding level, the EU would have experienced a more than 2% rate of growth.

9.13 * 2% = 0.18%

1.83% + 0.18% = 2.01%

For the abovementioned reasons, Greece has been selected as an extreme paradigm of country negatively affected by the dept crisis. The steep blue line between years 2006 and 2008 highlights the signs of a potential forthcoming prolonged recession, which stemmed even after that period. Data could be retrieved for the period of 1991-2020 with respect to GDP in Greece from ELSTAT. However, it is preferred to emphasize during a prolonged period of crisis so as to identify the trends of road accidents and to interpret the behavior of the road users.

For the same period of 1996-2010, data are collected from ELSTAT regarding the figures of road accidents in Greece. The table retrieved and the corresponding graph classify the road accidents according to the severity of the occurrence of the incidents. The categories, are accidents pertaining to the total amount of them, the slightly injured road users, the heavily injured road users and the deaths (referred as demises). The long-term trend, from 1996 to 2019, is similar in all 4 categories; that is, is declining. For reasons that have already been explained in the previous chapters and for uniformity purposes, it will be examined the potential relationship between demises and Real GDP (inflation adjusted).

Based on data of Table 6

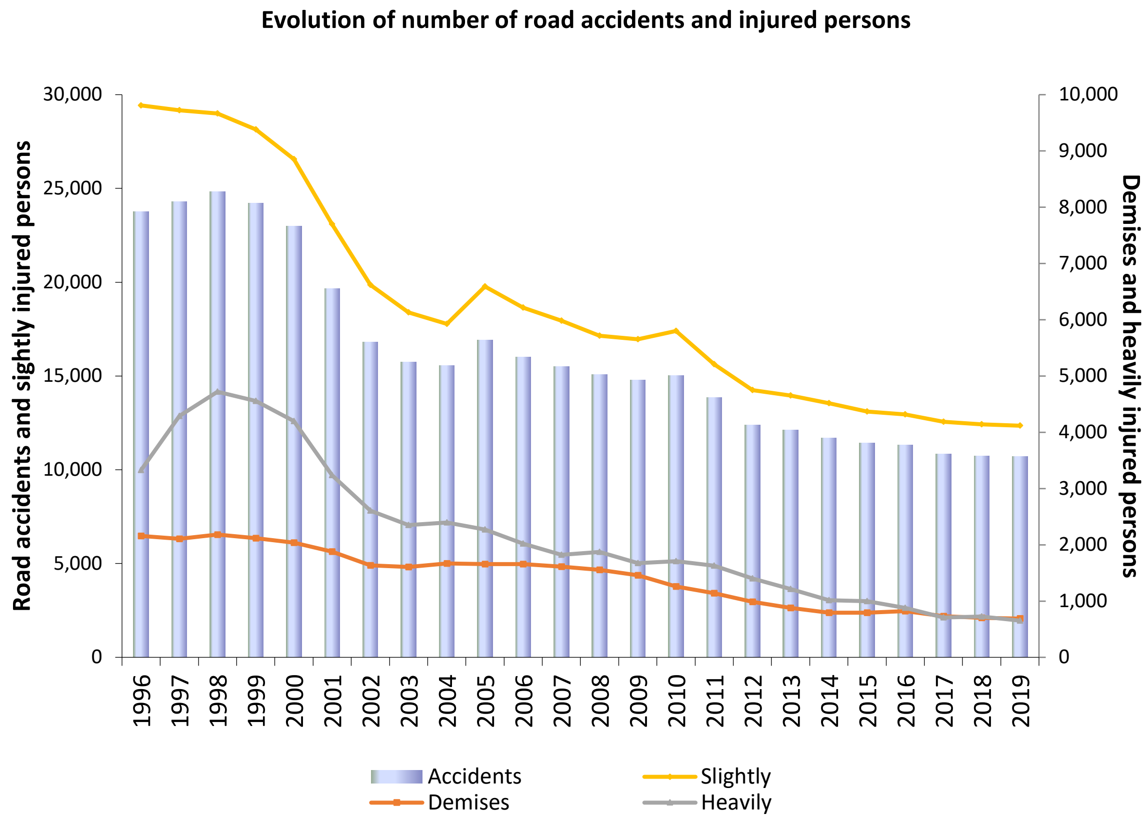

Figure 18 source: Evolution of number of accidents in Greece time series

source: https://www.statistics.gr/el/statistics/-/publication/SDT04/-

The long-term trend for demises is negatively slopping starting for the point of (1996, 2157) to the point (2019, 652). A PESTLE analysis model might explain the constant decline of the figure of demises in the long-term, nonetheless, in this text it will be investigated mainly the first "E" of the model; that is, Economic aspect.

In the following graph, are represented in a time series the Real GDP of Greece in hundreds of millions of € in the blue line, along with the total number of demises in the orange line. Real GDP, initially represented in billions of €, has been transformed to hundreds of millions of €, so that the data of blue and orange line can be represented within the range of values of [500, 2500]. This does not affect the final outcome, since the trend derived by the slopes of the curves remains unchanged.

Based on Table 6 and Table 7

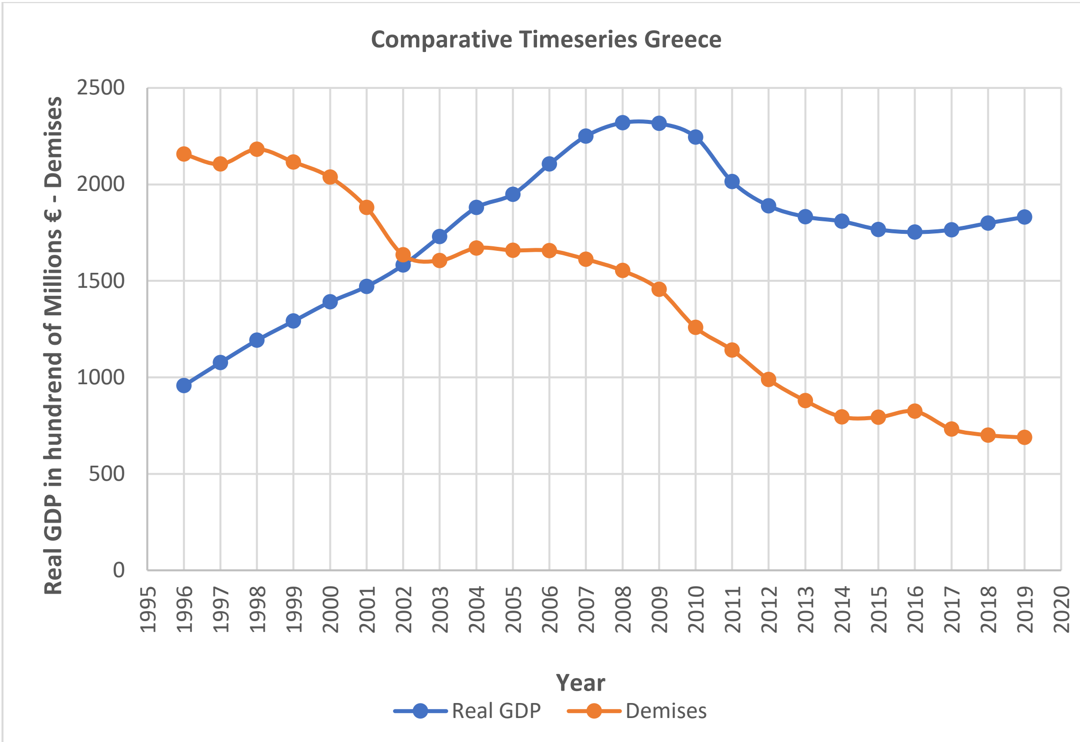

Figure 19.Comparative time series GDP in hundreds of millions of euros - demises

Computing the slopes of the curves from year 2009, when crisis outbroke in the Greece, to 2019 for both Real GDP and Demises occurs:

$$\lambda_{GDP1} = \frac{y2019GDP - y2009GDP}{x2019GDP - x2009GDP} = \frac{1830.64 - 2315.83}{2019 - 2009} = \frac{-485.19}{10} = -48.52$$

$$\lambda_{dem1} = \frac{y2019dem - y2009dem}{x2019dem - x2009dem} = \frac{688 - 1456}{2019 - 2009} = \frac{-768}{10} = -76.8$$

The calculated slopes above pertain to the average elasticities of Real GDP and demises respectively.

It can be interpreted as follows:

Over the 10year period of 2009-2019 in Greece an average annual loss of 48.52 hundred million of euros of Real GDP, or else 4.852 billion € occurred with an annual average decline of 76.8 total demises.

Another interpretation of the outcomes derives by the division of the demises with Real GDP.

$$\frac{\lambda GDP1}{\lambda dem1} = \frac{-48.52}{-76.8} = 0.63$$

For every 0.63 less hundred million of euros GDP per year, 1 less demise is observed.

In other words, for an annual loss of GDP by 630 million €, 10 less demises from road traffic accidents are observed in Greece over the period 2009-2019.

Now, it will be investigated what happened during the period 2010-2013. That period is considered the acute period of crisis, since 2010 is the very first year during which the crisis existed throughout the year. Data for this 4-year period may reveal that the impact of economic recession on risky driving was notably bigger.

$$\lambda_{GDP2} = \frac{y2013GDP - y2010GDP}{x2013GDP - x2010GDP} = \frac{1832.24 - 2245.21}{2013 - 2010} = \frac{-412.97}{3} = -137.66$$

$$\lambda_{dem2} = \frac{y2013dem - y2010dem}{x2013dem - x2010dem} = \frac{879 - 1258}{2013 - 2010} = \frac{-379}{3} = -126.33$$

The slopes of Real GDP and demises are significantly higher for the period 2010-2013 in absolute values, compared to the corresponding ones of the prolonged period of 2009-2019. Indeed,

$$|\lambda_{GDP2}| = 137.66 > 48.52 = |\lambda_{GDP1}|$$

$$|\lambda_{dem2}| = 126.33 > 76.8 = |\lambda_{dem1}|$$

$$\frac{\lambda GDP2}{\lambda dem2} = \frac{-137.66}{-126.33} = 1.09$$

For every 1.09 less hundred million of euros GDP per year, 1 less demise is observed.

For an annual loss of GDP by 1.09 billion €, 10 less demises from road traffic accidents are observed in Greece over the period 2010-2013.

Comparing the two periods, we derive:
2010-2013: *1.09 billion € average annual decline of GDP leads to 10 less demises annually*
2009-2019*: 0.63 billion € average annual decline of GDP leads to 10 less demises annually*

The impact of the financial crisis is evident in the decline of total demises by traffic accidents. The result can be generalized also for the total number of accidents, since the tendency of both total number of accidents and demises follow the same downward slopping pattern according to the **Table 6**.

5 Discussion

This particular study is chiefly dedicated to interpret the impact of Economy, that is; macroeconomic factors, on road accident mortality. However, some other criteria of PESTLE model e.g. social, political may apply and lead to conflicted inferences. In this text the findings refer to a bi-dimensional analysis; both referring to various countries and their respective economic dynamic for a certain year, and the medium-term perspective pertaining to comparison of a unique country over a period of time. The last is examined for turbulent times in economic terms; that is, a crisis. Several questions will be answered based on the findings of the previous chapter:

- How have the cross-sectional associations between prosperity and demises caused from accidents been developing in years 2010, 2018 and 2019 in European Union member-states?
- What is the general shape of the longitudinal relationship between road quality index in the EU state members and traffic accident mortality in a specific year, and what are the implications?
- What is the trend in global scale? Is there enough evidence that low-income countries experience more fatalities from road accidents?
- Could be stated that inhabitants of poor nations are more prone to get involved in road accidents more frequently than the respective habitants of rich nations?
- Do findings for Greece indicate a decline in road traffic accidents during the Economic recession as a result of the global financial crisis of 2008?

The GDP is a significant macroeconomic parameter that expresses the total output a country produces over a certain period of time, in most cases in an annual basis. The GDP per capita, reflects the average output an individual produces within a certain economy and within a certain period of time. This indicator emphasizes to how much "productive" and therefore, how much prosperous is an inhabitant of a certain country. The higher the average output produced, the higher the standards of living of a citizen, and in most cases, the higher quality of the products and services exchanged within the economy. The Real GDP per capita pertains to the corresponding GDP per capita, inflation adjusted, meaning that the prices level is held constant over time. That makes sense viewing an example bellow:

If the GDP per capita of a certain economy in a certain year is 10k and the next year the inflation is 100% due to various factors having happened in the global terrain, the corresponding GDP per capita of that economy will double in the next year (if the total output is constant). In other words, that country would present a GDP per capita of 20k, whereas the total output of the economy produced is unchanged.

Consequently, the Real GDP per capita is preferred, since the figures of the road traffic fatalities presented in "per million inhabitants" terms. In case of Greece, data referring to demises are expressed in absolute figures, and therefore the respective economic factor represented is the Real GDP instead of "per capita" terms.

5.1 Findings for the EU state members

The findings for the Regression Models, namely RM, applied in EU state members except Malta are the following based on **Figure 1**, **Figure 2**, **Figure 3**, **Figure 4**, **Figure 5**, and **Figure 6**:

		intercept	**coefficient of X**	**R^2**
2010	*linear RM*	92.81	-0.0009	36%
	log-log RM	15.4	-1.308	48%
2018	*linear RM*	71.02	-0.0006	35%
	log-log RM	7.9	-0.3925	58%

2019	*linear RM*	73.5	-0.0007	52%
	log-log RM	8.73	-0.48	68%

The linear model of 2019 gives significantly higher R^2 both in linear and log-log models comparing with the respective ones of 2010 and 2018. In all cases, the log-log regression model is observed to have a grater value than the coresponding linear models. The R^2 can take values between 0 and 1. The value of R^2 evaluates the scatter of the data points around the fitted regression model. A higher value of R^2 indicates a better fit for the model. (Institute, 2021) Assuming that all the log-log regression models fit better the represantation of our data some points can be stated regarding the 3 log-log models:

- All of them have a negative coefficient of the independent variable X, which indicates a downward slopping graph, and a negative relationship between Y and X. The higher the GDP per capita, the lower the value of deaths.
- The coefficients of the log-log models represent the elasticity of the dependent variable Y (deaths per million inhabitants) with respect to the independent variable X (Real GDP per capita).
- The elasticity is measured in absolute terms, therefore the elasticity of Y with respect to X is higher in 2010 (|-1.308|=1.308) and lower in 2018(|-0.3925|=0.3925). It can be derived that in the long run, the impact of GDP per capita is less in the number of deaths.
- The model for the year 2019 has the highest R^2=68%

The fall of demises due to road accidents, is 1.308%, 0.393% and 0.48% for 1% rise of GDP per capita for years 2010, 2018, and 2019 respectively. The corresponding fall in absolute terms of demises for 1% rise in Gross National Income withing Europe was found 0.359% in an other study. (Ali, Yaseen, & Khan, 2019) That study was referring to Europe as a continent, and one of the macroeconomic parameters chosen, similar to GDP, utilizied was GNI, which pertains to the total amount of money earned by a Nation's inhabitants and businesses. (Investopedia, 2021). The findings of that study even expressed in a different basis, seem closer the findings of this text regarding years 2018 and 2019.

Moreover, in all 3 years, Luxembourg consist of an outlier in the linear models, indicating that apparently the most prosperous / well-developed EU state member has a significantly high number of fatality rate in traffic accidents. That could be explained by the fact that it it the 3rd most populus EU state after the Netherlands and Belgium, in terms of density. Another possible explanation would be that in Luxembrourg there is the highest number of passenger vehicles per capita in circulation in EU., Luxembourg attracts visitors from neighboring countries, due to vicinity with France, Belgium and Germany. The rate of demises attributed to road accidents rely on road length, the number of vehicels, the population density and general economic conditions. (Prof. Atubi, 2015) In the table below are evident the high density of Luxembourg and its small land area. In the picture is depicted the fact that Luxembourg possesses the highest number of passenger cars in the EU according to Eurostat.

Country	Population (2020)	Yearly Change	Net Change	Density	Land Area (Km^2)
Netherlands	**17,134,872**	0.22 %	37,742	508	33,720
Belgium	**11,589,623**	0.44 %	50,295	383	30,280
Luxembourg	**625,978**	1.66 %	10,249	242	2,590
Germany	**83,783,942**	0.32 %	266,897	240	348,560

Figure 20. Population and density of EU state-members

source: https://www.worldometers.info/population/countries-in-europe-by-population/

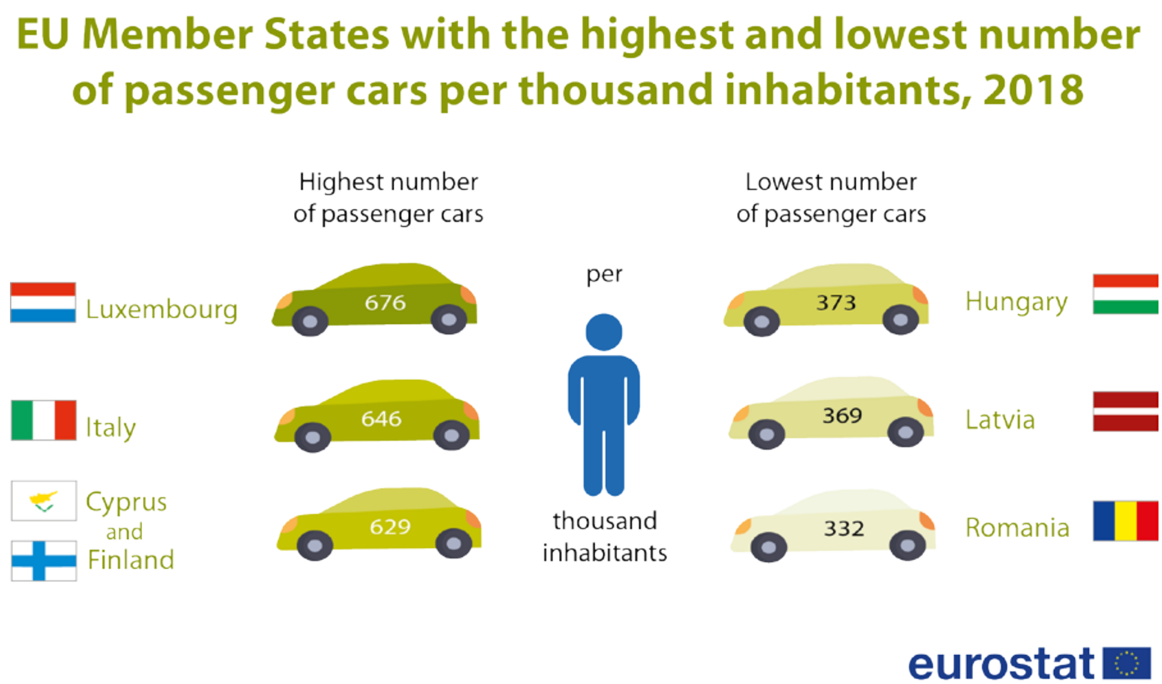

Figure 21.Numbers of highest and lowest number of passenger cars per thousand inhabitants of EU state-members

source: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Passenger_cars_infographics_2018_V2.png

Road Quality Index

Another potential factor that may lead to high numbers of road accidents is the quality of the road network. (Tehreem, 2012) According to another study conducted in Romania, the road quality along with the country strategy contribute to improving road performance and safety. Road safety performance indexes provide ideal conditions for safe traffic. The total number of registered road accidents are dependent on the road classification and the road performance is found to be directly proportional to the quality of the public roads network. (Cioca & 3, 2017)

The road quality index provided by World Economic Forum, using ascending scale from 1 to 7 is an indicator of average quality of the total road network of each EU country in 2018. The findings of the applied linear regression model, by designating

X as the road quality index value and Y, the dependent variable, the total number of deaths has given a negatively slopping relationship between those two variables, indeed:

Y = 118.68 – 13.323*X

Y = Road Fatalities per million inhabitants in 2018

X = Road Quality Index in 2018

The explanation of the selected model is, ceteris paribus, a country with a higher road quality index by 1 unit, happens to have 13 less fatalities caused by road accidents. Romania is the EU state member with 96 demises per million inhabitants in 2018, which is the highest amongst all countries and at the meantime, being the country with the lowest rating road network equal to 2.96. On the contrary, the Netherlands have the highest vote regarding the quality of road network (6.18) and at the same time, the fourth lowest number of demises (35), which is relatively close to the lowest one (29, Ireland).

A country with a high vote in road quality index, is more likely to be a rich nation. Moreover, the existence of a high road quality network, may be a trigger to incentivize the inhabitants to acquire top quality vehicles, devised and designed with world class active and passive safety systems. (Ali, Yaseen, & Khan, 2019). The growth impact of government spending for infrastructure is a parameter of crucial importance, indicates that public expenditure on transport and communications significantly raises growth. (W & S, 1993) Additionally, there is enough evidence that Physical infrastructure are positively and significantly related to growth in GDP per capita. (B, 1998) All in all, the relationship between high roads quality index and GDP is positive.

5.2 Findings for global scale research

The corresponding findings for both the linear and log-log regression models, applied in a global scale are the following based on **Figure 8** and **Figure 12**

		intercept	coefficient of X	R^2
Current estimates	*linear RM*	216.15	-0.0031	42%
	log-log RM	8.13	-0.365	62%

By the linear regression models turns out that there is a negative linear relationship between the variables X and Y. The richest the nation the less demises as a result of road accidents and vice versa. Liberia with 359 deaths, experiences the most traffic accident fatalities per million inhabitants and at the meantime it is considered the 10th most poor nation. The poorest nation Burundi experieces the 3rd worst worldwide position in traffic accident fatalities with 347 deaths.

According to the US National Library of Medicine, in 1998 developing countries accounted for more than 85% of all demises globally due to road traffic crashes, and for 96% of all children killed in a global scale. (Nantulya & Reich, 2002) The report states that injuries and demises due to road accidents consitute one major health issue. This is aligned with the WHO report which states that 90% of the world's road traffic fatalities occur in low- and middle-income countries, even though these countries have only about half the world's vehicles. (Organization, ROAD SAFETY:, 2017). This is congruent with the finding that heteroskedasticity is observed in both linear and log-log tranformed regression models. The corresponding Residual Plot in Figure 14 indicates that the data are not normally dispersed for the high-income nations, unlike low and midium-income nations. Moreover, among children aged 0-4 and 5-14 years old the number of fatalities in low income countries was observed to be six times greater than in high income countries in 1998. (Nantulya & Reich, 2002).

According to a study of the Global Burden of Disease, in the developing world, it will become the fifth leading cause of death, following HIV/AIDS, malaria, tuberculosis and other familiar killers. Poor nations account for 50 percent of the world's road traffic but 90 percent of the traffic demises. The costs linked with these deaths are a "poverty-inducing problem," Jose Luis Irigoyen stated, a specialist in the traffic safety sector at the World Bank. And he continued "It costs on average between 1 and 3 percent of GDP" in low- and middle-income countries, an amount that potentially could offset the billions of dollars in financial aid that these countries receive. (Dreazen, 2014).

Another aspect of the traffic fatalities afflicting medium and low-income countries of the developing world is that reducing road traffic demises can boost income growth. According to the report of the World bank, deaths and injuries from road traffic accidents affect medium- and long-term growth prospects by eliminating prime age adults from the work force, and declining productivity due to the burden of injuries. Using transparent data on demises and economic indicators from 135 countries, the study indicates that, on average, a 10% reduction in road traffic deaths raises per capita real GDP by 3.6% over a 24-year horizon. Moreover, over the long-term period 2014-38, decreasing by half demises and injuries due to road traffic could potentially add 22% to GDP per capita in Thailand, 15% in China, 14% in India, 7% in the Philippines and 7% in Tanzania. This could be declared as the reverse impact of road accident or risky driving on Economy. (Bank, 2017)

5.3 Findings for Greece

Another dimension of the research is the impact of economy within a certain economy; that is, an economy of a country over the long-run. Greece is chosen, because it was the EU state member mostly hit by the Global Financial Crisis of 2009. The time series graphs indicated that Greece reduced significantly the absolute number of demises by road accidents while embedded in a deep economic depression. In other words, its citizens proved to be more risk averse during that period which could be attributed in various factors.

Greece demonstrated one of the highest percentages of declining fatal road accidents within Europe throughout the period 2007-2017.According to the Institute of Public Health of American College of Greece the percentage of that decline reached 52%. That sound decrease is ascribed to the financial crisis that the country incurred, thanks to whom the Greeks appeared to drive more prudently and slowly so as to save fuel and prevent unexpected and unnecessary car repairs. (Team, 2018). The sound decreases in absolute numbers of demises which was recorded during crisis period is ascribed to the rise of fuel prices. According to the Technical University of Crete, the rising price of gasoline along with the high repairing costs, the brilliant news was that the road fatalities in 2012 almost reached the historical low number of 1974, when only 650k vehicles had been in circulation. Several parameters were investigated for research purposes which all incline in a decreasing number of road accidents. The most pivotal parameter was found to be the constant climbing fuel price.

Figure 22.Gasoline prices in Greece time series 2020-2020 in $

source: https://tradingeconomics.com/greece/gasoline-prices

According to the Association of Petroleum Trading Companies of Greece, cumulatively since 2009 this reduction exceeds 30%, while in the third quarter of 2012 compared to the corresponding period of 2011 it reaches 15%. (Dionysis, 2013). The tight interconnection between fuel consumption with the corresponding prices is depicted by the data issued by ELSTAT, which reflects the evolution of consumption during the memorandum period. The total fuel consumption was observed to be reduced during the period 2010-2015. During the acute period of crisis 2010-2013, it was noticed the highest percentage of that reduction:

- 2011 a decrease of -9% compared to 2010
- 2012 a decrease of -13.5% compared to 2011
- 2013 a decrease of -17.2% compared to 2012

(Naftemporiki-Economy, 2016)

For the respective annual periods the corresponding decline of the GDP is computed:

- $\frac{GDP2011}{GDP2010} = \frac{2013.77}{2245.21}$ = 0.897 = 10.3% decrease
- $\frac{GDP2012}{GDP2011} = \frac{1889.09}{2013.77}$ = 0.938 = 6.2 % decrease
- $\frac{GDP2013}{GDP2012} = \frac{1832.24}{1889.09}$ = 0.97 = 3% decrease

The percentage decrease of GDP in period 2010-2011 is greater than the respective decrease of fuel consumption for the same period. However, the in the next 2 periods the decline in fuel consumption is significantly higher compared to the corresponding fall in GDP. This could be explained by stating that the consumer base responds slowly to income changes it has incurred. After a certain period of time - one year in this case- the elasticity of demand of fuel with respect to their disposable income is significantly higher.

By reviewing the respective fall in number of road accident fatalities occurs:

- $\frac{Demises2011}{Demises2010} = \frac{1141}{1258}$ = 0.907 = 9.3% decrease
- $\frac{Demises2012}{Demises2011} = \frac{988}{1141}$ = 0.866 = 13.4 % decrease
- $\frac{Demises2013}{Demises2012} = \frac{879}{988}$ = 0.89 = 11% decrease

The percentage changes (fall) in periods 2011-2021, 2012-2013 are significantly higher when it comes to road accident fatalities compared to the respective ones of GDP. Therefore, it can be inferred that the impact of the Economy to fatalities is elastic. In other words, a low decrease of the total output that produces Greece, led to a higher decrease in number of demises attributed to road accidents. This is apparent in the graph for the period 2011-2016, where the line of Real GDP is downward slopping and resembles to a straight line. The corresponding line of Demises is downward slopping but steeper as it is observed in **Figure 19**. This could be explained by the fact that the impact of Economy is high in forming the number of road accidents, especially during a period of crisis. Even a low loss of income per citizen, may lead to containment of taking risky decisions. Driving prudently is considered a form of adoption of a low-risk way of life.

6 Conclusion

In this text has been analyzed the effect of the economy on risky driving. Risky driving has been proved to be a scourge with severe and unbearable consequences afflicting a wide range of stakeholders within societies. Every year approximately 1.35 million of people die as a result of road traffic crashes, 93% of whom occur in low and middle-income countries. (Organization, Road traffic injuries, 2020)A severe side effect as a result of road accidents is the high bill countries have to confront with, both explicitly, by covering intolerably high medical expenses, and road network repairs, and implicitly by losing young people who potentially could have contributed to economic growth. (Bhavan, 2019) (Carriero & Azeredo, 2018). The situation is rather reverse in the developed world. The ownership of modern vehicles complying with high active and passive safety standards, the existence of world-class road networks, the lower levels of corruption, along with the constantly optimized education systems contribute all-together in the reduction of road accidents. (Ali, Yaseen, & Khan, 2019)

Few studies have been conducted to identify the association between economic growth or recession and number of car crashes or fatalities as a result of them. As from the beginning of the twenty first century, China has reached a two-digit annual average GDP growth rate. This growth rate led the number of car accident fatalities to rise from 61 per million inhabitants in 1996, to 86 in 2002. (Iwata, 2020). On the other hand, the number of car accidents in Greece was reduced during the global financial crisis. (Mpogas, Kopelias, Mitropoulos, & Kepaptsoglou, 2016) This is also reaffirmed by plenty reports and articles posted in the Hellenic press. This is confirmed and discussed in this text. Several factors contributed to that fact, from which could be stated that citizens of Greece appeared to be more risk averse in terms of driving during turbulent times. This is the case too for the United States of America during the Great recession. It was proved that temporary economic recessions are associated with lower mortality, than expected, at the population level. (He, 2016)

The outcomes and inferences of this thesis is congruent with the core researches regarding the poor and middle-income countries. The Regression models utilized by applying the Ordinary Least Squares Estimation method have indicated a strong negative linear relationship between GDP per capita and road accidents fatality. The data were heteroskedastic in both models used. The higher deviations (outliers) were observed in high-income countries. The low and middle-income countries are the most afflicted ones counting for approximately 90% of global road accident fatalities. Referring to the high-income nations the situation is reversed. (Kopits & Cropper, 2003).

More research could be conducted in the future with regard the developed and third world, referring to the impact of economic cycle to the number of fatalities. More comprehensive approaches by applying more complex research tools such as PESTLE or SWOT analysis could be deployed for those academic purposes. The significance of the research is considered imperative. Constructing high quality road networks and efficient enforcement of traffic laws by the governments are considered crucial. Moreover, more strict legislation might be enforced regarding the regular inspection of vehicles, strict inspection for the driving license, and oversee of medical fitness of drivers by conducting frequent medical checkups. The governments should also craft various media channels for the self-awareness of the citizens about loss due to road accidents. The less traffic fatalities one country experiences, the higher the boost income growth due to low rates of young workforce lost. The reverse effect of economy deriving from high rated of demises attributed to road accidents may incentivize governments to implement extra preventive measures. More scientific tools, sophisticated data and information can be granted to governments, so as to hinder the high numbers of demises from car crashes and to design new frameworks as described above so as to cope with them efficiently.

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Appendices

A. Tables of Data Collected and Transformed for EU state-members

2010 Real GDP per Capita in EU state-members

Year 2010
X = Real GDP per Capita
Y = Road Fatalities
LN(X), LN(Y)

Table 1.EU state-members 2010

source: https://ec.europa.eu/eurostat/databrowser/view/sdg_08_10/default/table?lang=en

https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/people/road-fatalities_en

EU state-member	GDP per capita 2010	Road Fatalities per million Inhabitants in 2010	LN(GDP per capita 2010)	LN(Road Fatalities per million Inhabitants in 2010)
Belgium	33,330	77	10.414	4.344
Bulgaria	5,050	105	8.527	4.654
Czechia	15,020	77	9.617	4.344
Denmark	43,840	46	10.688	3.829
Germany	31,940	45	10.372	3.807
Estonia	11,150	59	9.319	4.078
Ireland	36,770	47	10.512	3.850
Greece	20,150	113	9.911	4.727
Spain	23,040	53	10.045	3.970

France	30,690	64	10.332	4.159
Italy	26,930	70	10.201	4.248
Cyprus	23,400	73	10.060	4.290
Latvia	8,520	103	9.050	4.635
Lithuania	9,050	95	9.111	4.554
Luxembourg	79,160	64	11.279	4.159
Hungary	9,960	74	9.206	4.304
Netherlands	38,470	32	10.558	3.466
Austria	35,390	66	10.474	4.190
Poland	9,400	103	9.148	4.635
Portugal	16,990	80	9.740	4.382
Romania	6,200	117	8.732	4.762
Slovenia	17,750	67	9.784	4.205
Slovakia	12,560	65	9.438	4.174
Finland	35,080	51	10.465	3.932
Sweden	39,950	28	10.595	3.332

2018 Real GDP per Capita in EU state-members

Year 2018

X = Real GDP per Capita

Y = Road Fatalities

LN(X), LN(Y)

Table 2. EU state-members 2018

source: https://ec.europa.eu/eurostat/databrowser/view/sdg_08_10/default/table?lang=en https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/people/road-fatalities_en

EU state-member	GDP per capita 2018	Road Fatalities per million Inhabitants in 2018	LN(GDP per capita 2018)	LN(Road Fatalities per million Inhabitants in 2018)
Belgium	35,510	53	10.478	3.970
Bulgaria	6,550	87	8.787	4.466
Czechia	17,980	62	9.797	4.127
Denmark	48,530	30	10.790	3.401
Germany	35,720	40	10.483	3.689
Estonia	15,070	51	9.620	3.932
Ireland	57,780	29	10.964	3.367
Greece	17,400	65	9.764	4.174
Spain	24,910	39	10.123	3.664
France	32,860	49	10.400	3.892
Italy	26,780	55	10.195	4.007
Cyprus	24,120	57	10.091	4.043
Latvia	12,180	78	9.408	4.357
Lithuania	13,390	62	9.502	4.127
Luxembourg	83,470	60	11.332	4.094
Hungary	12,680	65	9.448	4.174
Netherlands	41,450	35	10.632	3.555
Austria	37,800	46	10.540	3.829
Poland	12,420	76	9.427	4.331
Portugal	18,190	66	9.809	4.190
Romania	8,700	96	9.071	4.564
Slovenia	20,220	44	9.914	3.784
Slovakia	15,520	48	9.650	3.871
Finland	36,780	43	10.513	3.761
Sweden	43,760	32	10.686	3.466

2019 Real GDP per Capita in EU state-members

Year 2019

X = Real GDP per Capita

Y = Road Fatalities

LN(X), LN(Y)

Table 3.EU state-members 2019

source: https://ec.europa.eu/eurostat/databrowser/view/sdg_08_10/default/table?lang=en https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/people/road-fatalities_en

EU state-member	GDP per capita 2019	Road Fatalities per million Inhabitants in 2019	LN(GDP per capita 2019)	LN(Road Fatalities per million Inhabitants in 2019)
Belgium	35,940	56	10.490	4.025
Bulgaria	6,840	89	8.831	4.489
Czechia	18,330	58	9.816	4.060
Denmark	49,720	35	10.814	3.555
Germany	35,840	37	10.487	3.611
Estonia	15,760	39	9.665	3.664
Ireland	60,170	29	11.005	3.367
Greece	17,740	65	9.784	4.174
Spain	25,200	36	10.135	3.584
France	33,270	48	10.412	3.871
Italy	26,920	55	10.201	4.007
Cyprus	24,570	59	10.109	4.078
Latvia	12,510	69	9.434	4.234
Lithuania	14,010	66	9.548	4.190
Luxembourg	83,640	36	11.334	3.584
Hungary	13,260	62	9.493	4.127
Netherlands	41,870	34	10.642	3.526
Austria	38,170	46	10.550	3.829
Poland	13,000	77	9.473	4.344

Portugal	18,590	61	9.830	4.111
Romania	9,120	96	9.118	4.564
Slovenia	20,700	49	9.938	3.892
Slovakia	15,860	51	9.672	3.932
Finland	37,170	37	10.523	3.611
Sweden	43,900	22	10.690	3.091

2018 Quality of Road Index

Year 2018

X = Quality of Roads

Y = Road Fatalities

Table 4.EU state-members Road Quality Index

source: https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/investments-infrastructure/quality-roads_en https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/people/road-fatalities_en

Country	Roads Quality Index in 2018	Road Fatalities per million Inhabitants in 2018
Belgium	4.39	53
Bulgaria	3.52	87
Czechia	3.95	62
Denmark	5.55	30
Germany	5.46	40
Estonia	4.68	51
Ireland	4.48	29
Greece	4.73	65
Spain	5.63	39
France	5.96	49
Italy	4.39	55
Cyprus	5.22	57
Latvia	3.45	78
Lithuania	4.70	62
Luxembourg	5.34	60
Hungary	3.89	65

Netherlands	6.18	35
Austria	5.89	46
Poland	4.14	76
Portugal	6.05	66
Romania	2.96	96
Slovenia	4.66	44
Slovakia	3.96	48
Finland	5.26	43
Sweden	5.57	32

B. Tables of Data Collected and Transformed in global scale

Estimations of GDP per Capita

Current Estimations

X = GDP per Capita

Y = Road Fatalities

LN(X) & LN(Y)

Table 5. Global scale current estimations

sources: https://www.imf.org/en/Publications/WEO/weo-database/2020/October/download-entire-database https://www.who.int/data/gho/data/indicators/indicator-details/GHO/estimated-number-of-road-traffic-deaths

Country	GDP per capita (IMF) 2020 estimates	Fatalities (WHO) estimates	LN(GDP per capita estimates)	LN(Fatalities WHO estimates)
Luxembourg	109602	57	11.6046109	4.043051268
Switzerland	81867	27	11.31285126	3.295836866
Ireland	79669	41	11.28563583	3.713572067
Norway	67989	27	11.12710121	3.295836866
United States	63051	124	11.0516992	4.820281566
Singapore	58484	28	10.97650849	3.33220451

Denmark	58439	40	10.97573875	3.688879454
Iceland	57189	66	10.95411685	4.189654742
Qatar	52751	93	10.87333801	4.532599493
Australia	51885	56	10.85678501	4.025351691
Netherlands	51290	38	10.84525108	3.63758616
Sweden	50339	28	10.8265354	3.33220451
Austria	48634	52	10.79207815	3.951243719
Finland	48461	47	10.78851463	3.850147602
Germany	45466	41	10.72472007	3.713572067
Belgium	43814	58	10.68770868	4.060443011
Canada	42080	58	10.64732785	4.060443011
Israel	41560	42	10.63489345	3.737669618
France	39257	55	10.57788505	4.007333185
United Kingdom	39229	31	10.57717155	3.433987204
Japan	39048	41	10.57254694	3.713572067
New Zealand	38675	78	10.56294868	4.356708827
United Arab Emirates	31948	181	10.37186486	5.198497031
Italy	30657	56	10.3306163	4.025351691
South Korea	30644	98	10.33019216	4.584967479
Malta	28469	61	10.25657105	4.110873864
Taiwan	26910	182	10.20025324	5.204006687
Spain	26832	41	10.19735048	3.713572067
Cyprus	26240	51	10.17504024	3.931825633
Slovenia	25039	64	10.12818989	4.158883083
Brunei	23117	236	10.04832356	5.463831805
Estonia	22986	61	10.04264061	4.110873864
Czech Republic	22627	59	10.02689916	4.077537444
Kuwait	22252	176	10.01018717	5.170483995
Portugal	21608	74	9.980818895	4.304065093
Lithuania	19883	80	9.897620374	4.382026635

Saudi Arabia	19587	288	9.88262136	5.66296048
Slovakia	18669	61	9.834619673	4.110873864
Greece	18168	92	9.807417084	4.521788577
Latvia	17230	93	9.75440733	4.532599493
Trinidad and Tobago	16197	121	9.692581319	4.795790546
Barbados	16082	56	9.685455913	4.025351691
Hungary	15373	78	9.640368003	4.356708827
Uruguay	15332	134	9.637697427	4.8978398
Poland	15304	97	9.635869511	4.574710979
Oman	14423	161	9.576579434	5.081404365
Antigua and Barbuda	14159	79	9.558105743	4.369447852
Panama	14090	143	9.553220605	4.96284463
Croatia	14033	81	9.549166978	4.394449155
Romania	12813	103	9.45821556	4.634728988
Chile	12612	125	9.442404021	4.828313737
Seychelles	12323	159	9.419222714	5.068904202
Costa Rica	11629	167	9.361257257	5.117993812
China	10839	182	9.29090602	5.204006687
Malaysia	10192	236	9.229358378	5.463831805
Russia	9972	180	9.207536445	5.192956851
Bulgaria	9826	103	9.192787213	4.634728988
Saint Lucia	9780	354	9.188094763	5.869296913
Mauritius	8951	137	9.099520537	4.919980926
Kazakhstan	8782	176	9.080459451	5.170483995
Serbia	8506	74	9.048527076	4.304065093
Argentina	8433	140	9.03990786	4.941642423
Guyana	8073	246	8.996280439	5.505331536
Mexico	8069	131	8.995784838	4.875197323
Montenegro	7933	107	8.978786553	4.672828834
Turkey	7715	123	8.950921765	4.812184355

Dominica	7709	109	8.950143756	4.691347882
Turkmenistan	7507	145	8.923591198	4.976733742
Dominican Republic	7445	346	8.915297945	5.846438775
Thailand	7295	327	8.894944461	5.789960171
Iran	7257	205	8.889721799	5.323009979
Gabon	7185	232	8.879750799	5.446737372
Equatorial Guinea	7131	246	8.872206756	5.505331536
Botswana	6558	238	8.788440957	5.472270674
Brazil	6450	197	8.77183541	5.283203729
Belarus	6134	89	8.721602345	4.48863637
North Macedonia	6019	64	8.702676412	4.158883083
Peru	5845	135	8.673341874	4.905274778
Bosnia and Herzegovina	5762	157	8.659039916	5.056245805
Ecuador	5316	213	8.57847642	5.361292166
Jamaica	5221	136	8.560444233	4.912654886
Colombia	5207	185	8.557759153	5.220355825
Paraguay	4909	227	8.498825534	5.424950017
Albania	4898	136	8.496582238	4.912654886
South Africa	4736	259	8.462948177	5.556828062
Iraq	4438	207	8.397959103	5.332718793
Georgia	4405	153	8.390495538	5.030437921
Armenia	4315	171	8.369852604	5.141663557
Moldova	4268	97	8.358900612	4.574710979
Guatemala	4240	166	8.352318548	5.111987788
Suriname	4199	145	8.342601681	4.976733742
Jordan	4174	244	8.336630088	5.497168225
Azerbaijan	4125	87	8.324821299	4.465908119
Namibia	4052	304	8.306965865	5.717027701
Indonesia	4038	122	8.303504799	4.804021045
Mongolia	3990	165	8.29154651	5.105945474

El Salvador	3821	222	8.248267447	5.402677382
Belize	3734	283	8.225235324	5.645446898
Sri Lanka	3698	149	8.215547412	5.003946306
Egypt	3561	97	8.177796683	4.574710979
Vietnam	3498	264	8.159946656	5.575949103
Bhutan	3431	174	8.140607043	5.159055299
Ukraine	3425	137	8.138856751	4.919980926
Eswatini	3415	269	8.135932772	5.59471138
Philippines	3373	123	8.123557835	4.812184355
Cape Verde	3358	250	8.119100838	5.521460918
Bolivia	3322	155	8.10832229	5.043425117
Tunisia	3295	228	8.100161447	5.429345629
Libya	3282	261	8.096208272	5.564520407
Morocco	3121	196	8.045908742	5.278114659
Lebanon	2745	181	7.917536354	5.198497031
Papua New Guinea	2652	142	7.883069351	4.955827058
Laos	2567	166	7.850493181	5.111987788
Honduras	2412	167	7.788211558	5.117993812
Solomon Islands	2367	174	7.76937861	5.159055299
Côte d'Ivoire	2281	236	7.732369222	5.463831805
Ghana	2188	249	7.690743164	5.517452896
Nigeria	2149	214	7.672757897	5.365976015
Congo, Republic of the	2128	274	7.66293785	5.613128106
Syria	2114	265	7.656337166	5.579729826
Kenya	2075	278	7.637716433	5.627621114
Angola	2021	236	7.611347717	5.463831805
São Tomé and Príncipe	1912	275	7.555905094	5.616771098
Bangladesh	1888	153	7.543273347	5.030437921
India	1877	226	7.537430037	5.420534999
Mauritania	1791	247	7.490529402	5.509388337

Uzbekistan	1763	115	7.474772182	4.744932128
Venezuela	1739	337	7.461065514	5.82008293
Cambodia	1572	178	7.360103973	5.18178355
Cameroon	1493	301	7.308542798	5.707110265
East Timor	1456	127	7.283448229	4.844187086
Senegal	1455	234	7.28276118	5.455321115
Comoros	1337	265	7.198183577	5.579729826
Myanmar	1333	199	7.19518732	5.293304825
Benin	1259	275	7.138073034	5.616771098
Kyrgyzstan	1148	154	7.045776577	5.036952602
Nepal	1116	159	7.017506143	5.068904202
Tanzania	1106	292	7.008505182	5.676753802
Guinea	1019	282	6.926577033	5.641907071
Ethiopia	974	267	6.881411304	5.587248658
Lesotho	924	289	6.828712072	5.666426688
Zimbabwe	922	347	6.826545224	5.84932478
Uganda	915	290	6.818924065	5.669880923
Mali	899	231	6.801283034	5.442417711
Tajikistan	834	181	6.726233402	5.198497031
Rwanda	823	297	6.712956201	5.693732139
Burkina Faso	769	305	6.64509097	5.720311777
Guinea-Bissau	767	311	6.642486801	5.739792912
Gambia, The	746	297	6.6147256	5.693732139
Sudan	735	257	6.599870499	5.549076085
Togo	690	292	6.536691598	5.676753802
Liberia	654	359	6.483107351	5.883322388
Chad	640	276	6.461468176	5.620400866
Eritrea	585	253	6.371611847	5.533389489
Niger	536	262	6.284134161	5.568344504
Madagascar	515	286	6.244166901	5.655991811

Afghanistan	499	151	6.212606096	5.017279837
Central African Republic	480	336	6.173786104	5.81711116
Congo, Democratic Republic	457	274	6.124683391	5.613128106
Mozambique	455	301	6.120297419	5.707110265
Malawi	399	310	5.988961417	5.736572297
South Sudan	303	299	5.713732806	5.700443573
Burundi	264	347	5.575949103	5.84932478

C. Tables of Data Collected for Greece

Road accidents in Greece

Years 1996-2019

Table 6. Traffic accidents in Greece 1996-2019

source: https://www.statistics.gr/el/statistics/-/publication/SDT04/-

Year	Accidents					Afflicted persons						
	Total	Fatal	%	Non fatal	%	Total	Demises	%	Injured			
									Heavily	%	Slightly	%
1996	23,775	1,870	7.87	21,905	92.13	34,912	2,157	6.18	3,327	9.53	29,428	84.29
1997	24,295	1,837	7.56	22,458	92.44	35,569	2,105	5.92	4,288	12.06	29,176	82.03
1998	24,819	1,921	7.74	22,898	92.26	35,903	2,182	6.08	4,720	13.15	29,001	80.78
1999	24,231	1,876	7.74	22,355	92.26	34,822	2,116	6.08	4,558	13.09	28,148	80.83
2000	23,001	1,803	7.84	21,198	92.16	32,800	2,037	6.21	4,200	12.8	26,563	80.98
2001	19,671	1,669	8.48	18,002	91.52	28,216	1,880	6.66	3,238	11.48	23,098	81.86
2002	16,809	1,438	8.55	15,371	91.45	24,093	1,634	6.78	2,608	10.82	19,851	82.39
2003	15,751	1,400	8.89	14,351	91.11	22,342	1,605	7.18	2,348	10.51	18,389	82.31
2004	15,547	1,484	9.55	14,063	90.45	21,849	1,670	7.64	2,395	10.96	17,784	81.4
2005	16,914	1,482	8.76	15,432	91.24	23,706	1,658	6.99	2,270	9.58	19,778	83.43
2006	16,019	1,501	9.37	14,518	90.63	22,332	1,657	7.42	2,021	9.05	18,654	83.53
2007	15,499	1,442	9.3	14,057	90.7	21,378	1,612	7.54	1,821	8.52	17,945	83.94
2008	15,083	1,411	9.35	13,672	90.65	20,563	1,553	7.55	1,872	9.1	17,138	83.34
2009	14,789	1,296	8.76	13,493	91.24	20,097	1,456	7.24	1,676	8.34	16,965	84.42
2010	15,032	1,142	7.6	13,890	92.4	20,366	1,258	6.18	1,709	8.39	17,399	85.43
2011	13,849	1,051	7.59	12,798	92.41	18,400	1,141	6.2	1,626	8.84	15,633	84.96

2012	12,398	908	7.32	11,490	92.68	16,628	988	5.94	1,399	8.41	14,241	85.64
2013	12,109	814	6.72	11,295	93.28	16,054	879	5.48	1,212	7.55	13,963	86.98
2014	11,690	739	6.32	10,951	93.68	15,359	795	5.18	1,016	6.62	13,548	88.21
2015	11,440	741	6.48	10,699	93.52	14,889	793	5.33	999	6.71	13,097	87.96
2016	11,318	772	6.82	10,546	93.18	14,649	824	5.62	879	6	12,946	88.37
2017	10,848	679	6.26	10,169	93.74	14,002	731	5.22	706	5.04	12,565	89.74
2018	10,737	645	6.01	10,092	93.99	13,849	700	5.05	727	5.25	12,422	89.7
2019	10,712	656	6.12	10,056	93.88	13,690	688	5.03	652	4.76	12,350	90.21

Real GDP in Greece

Years 1996-2019

Table 7.Real GDP of Greece 2000-2019 in hundreds of millions €

source: https://www.statistics.gr/el/statistics/-/publication/SEL15/-

Year	Real GDP
1996	957.27
1997	1076.57
1998	1191.8
1999	1291.11
2000	1390.33
2001	1470.83
2002	1581.64
2003	1729.33
2004	1879.59
2005	1948.76
2006	2105.04
2007	2249.94
2008	2319.15

2009	2315.83
2010	2245.21
2011	2013.77
2012	1889.09
2013	1832.24
2014	1808.7
2015	1766.19
2016	1752.48
2017	1764.69
2018	1799.14
2019	1830.64

D. Specification tests

Specification Tests for Log-Log regression model in global scale

Ramsey RESET Test

Table 8.Ramsey REST Test for log-log model

Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Squares of fitted values
Specification: LN_FATALITIES_WHO_ESTIMATES_ C LN_GDP_PER_CAPITA_ESTIMATES_

	Value	df	Probability
t-statistic	4.756207	160	0.0000
F-statistic	22.62151	(1, 160)	0.0000
Likelihood ratio	21.55543	1	0.0000

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	3.353324	1	3.353324
Restricted SSR	27.07110	161	0.168143
Unrestricted SSR	23.71778	160	0.148236

LR test summary:

	Value
Restricted LogL	-84.97138
Unrestricted LogL	-74.19366

Unrestricted Test Equation:
Dependent Variable: LN_FATALITIES_WHO_ESTIMATES_
Method: Least Squares
Date: 04/15/21 Time: 15:23
Sample: 1 163
Included observations: 163

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	36.06083	5.876105	6.136859	0.0000
LN_GDP_PER_CAPITA_ESTIMATES_	-2.166538	0.379278	-5.712263	0.0000
FITTED^2	-0.495593	0.104199	-4.756207	0.0000

R-squared	0.666321	Mean dependent var	4.975204
Adjusted R-squared	0.662150	S.D. dependent var	0.662392
S.E. of regression	0.385014	Akaike info criterion	0.947162
Sum squared resid	23.71778	Schwarz criterion	1.004102
Log likelihood	-74.19366	Hannan-Quinn criter.	0.970279
F-statistic	159.7514	Durbin-Watson stat	2.143196
Prob(F-statistic)	0.000000		

White Test

Table 9.White Test for log-log model

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	7.968093	Prob. F(2,160)	0.0005
Obs*R-squared	14.76444	Prob. Chi-Square(2)	0.0006
Scaled explained SS	14.69044	Prob. Chi-Square(2)	0.0006

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/15/21 Time: 15:38
Sample: 1 163
Included observations: 163

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.158746	0.608093	-0.261056	0.7944
LN_GDP_PER_CAPITA_ESTIMATES_^2	0.001486	0.008251	0.180103	0.8573
LN_GDP_PER_CAPITA_ESTIMATES_	0.024500	0.142998	0.171331	0.8642

R-squared	0.090579	Mean dependent var	0.166080
Adjusted R-squared	0.079212	S.D. dependent var	0.237925
S.E. of regression	0.228308	Akaike info criterion	-0.098013
Sum squared resid	8.339893	Schwarz criterion	-0.041073
Log likelihood	10.98805	Hannan-Quinn criter.	-0.074896
F-statistic	7.968093	Durbin-Watson stat	2.042255
Prob(F-statistic)	0.000503		