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Determinants of Traffic Fatalities in Sweden

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Abstract

This paper presents an empirical investigation of the casualties of road traffic fatalities in Sweden from the perspective of different socio-economic factors. We use the annual data on traffic fatalities, income level, vehicle park, population, traffic offence, fuel price and unemployment rate over the period 1992-2009. Paper addresses the methodological issues related to the nonstationarity problem and reflects the outcome in the model specification. Results indicate that driving license revocations due to the drunk driving are positively associated with traffic fatalities, which implies that police strengthens the enforcement of traffic laws after the increase in traffic fatality rate. Moreover, an increase in unemployment rate reduces traffic fatalities through a negative impact on vehicle ownership. At last, a traffic fatality rate tends to decrease over time due to the advances in vehicle design, highway quality, medical care and other traffic safety measures.

JEL classification numbers: C22, C51, O18, R41
Keywords: traffic fatality, accident, unit root, time series

1 Introduction

The problem of death and injury due to the road traffic accidents yield medical, social and economic problems to society which requires advancing institutional responsibility for road safety. Therefore, providing a greater safety on roads and extenuating the harmful effects of vehicles on human health is one of the global policy issues to be prioritized.

The World Health Organization (WHO) reports about 1.3 million deaths in road accidents annually, which accounts for 2.2% of total deaths in the world. The

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projected trends in global mortality shows that there will be a 28% increase in global death due to the injury between 2004 and 2030, which mainly results from the increasing number of road accident deaths. Road traffic accidents deaths are projected to increase to 2.4 million in 2030, primarily due to the increased motor vehicle ownership and use associated with economic growth in low and middle income countries. This implies that, road traffic accidents will raise from ninth leading cause of death globally in 2004 to the fifth in 2030.

The economic consequences of road traffic accidents are also significant, in terms of both lost productivity and all healthcare costs as an immediate corollary. The World Bank states that road accidents cost a country approximately 1 to 3% of its annual Gross National Product (GNP). These expenses constitute a significant share of national economy, which may impede the economic and social development of the country. The global cost is estimated to be USD 518 billion per year. Low-income and middle-income countries account for USD 65 billion, more than they receive in development assistance. By contrast, a modest amount of resources is invested in preventing the road accidents and injuries. The estimated global research and development funding for road traffic accidents comprise USD 24-33 millions. Comparatively little is spent on implementation, even though many interventions that would prevent the accidents and injuries are well known, well tested, cost-effective and publicly acceptable (WHO, 2004).

Identifying the factors that can shed light on the incidence of traffic accidents and a thorough analysis of the circumstances that lead to traffic accidents is fundamental in developing traffic safety policies. Therefore, investigating the magnitude, scope, characteristics and consequences of road traffic accidents can increase the effectiveness of interventions.

In the presence of complexity of the road traffic system, analyzing the factors that has an impact on road traffic fatality is purposed in this research. Therefore, we integrate the findings of past works with quantitative analysis made on different countries to empirically analyze the traffic accidents in Sweden. We model a traffic fatality rate as a function of several socio-economic factors and use the aggregate annual data for the period 1992-2009. Results indicate that driving license revocations due to the drunk driving might be positively associated with traffic fatality rate. This unexpected positive relationship might be explained by more stringent enforcement of traffic safety regulations by police after traffic accidents. We also find that as unemployment rate increases, traffic fatalities tend to decline due to worsening of the purchasing power, which may affect the affordability of vehicle ownership. Consequently, the fewer vehicles in traffic may decrease the probability of traffic accidents. Finally, we find that the traffic fatality is likely to decrease over time due to the improvement of driving skills, vehicle design, highway quality, medical care and other traffic safety measures.

The contribution of this study might be reflected in three regards. First, we address some methodological issues that are present in previous studies. Second, the outcome of this study may facilitate designing the efficient policy interventions to improve traffic safety by considering the factors that have a significant impact on

traffic fatality. At last, this is the first empirical study that analyzes the incidence of traffic fatalities using socio-economic factors for the case of Sweden.
The paper is constructed as follows. Section 2 provides a literature review. The Swedish passenger car traffic performance is discussed in Section 3. Model specification and data description are presented in Sections 4 and 5, respectively. Section 6 provides the results of a unit root test, multicollinearity test, multiple regressions, as well as the result discussion. Section 4 concludes the paper.

2 Literature review

Traffic safety literature discusses several socio-economic factors that might be the determinants of traffic fatalities. For instance, the level of economic performance of a country may have an impact on traffic fatality rate. According to the World Health Organization (2004), while developing countries own only about 32 % of the world's motor vehicles, they account for 85 % of the 1 million individuals killed and 24 million injured in road traffic accidents each year (Anbarci et al., 2006).
Bishai et al. (2006) investigate the impact of the Gross Domestic Product (GDP) per capita on traffic fatality rate in the low-income and wealthy countries. The results indicate that a 10% increase in the GDP in a low-income country is expected to raise the number of accidents by 7.9%, the number of traffic injuries by 4.7%, and the number of fatalities by 3.1% through a mechanism that is independent of a population size, vehicle counts, oil use, and roadway availability. Increases in GDP in rich countries appear to reduce the number of traffic fatalities, but do not reduce the number of accidents or injuries, all else equal. Greater petrol use and alcohol use are related to more traffic fatalities in rich countries. In low-income countries, a rise in traffic accidents, injuries, and fatalities accompanies economic growth. After a certain threshold in economic growth per capita, there is no longer an increase in the number of fatalities, though the number of accidents and injuries continue to increase with growth.
Examining the impact of income growth on the traffic fatality rates, Kopits and Cropper (2003) argue that the relationship between motor vehicle fatality rate and per capita income at first increases with per capita income, reaches a peak, and then declines. The reason is that at low income levels, the rate of increase in motor vehicle outpaces the decline in fatalities per motor vehicle. At higher income levels, the reverse occurs. Therefore, the observed patterns illustrate a decline in fatalities in wealthy countries, whereas an increase in fatalities in developing countries. Anbarci et al. (2006) explaining this phenomenon argue that in a low-income country with low motorization rates, there is a low risk of traffic fatality. However, as per capita income increases, the motorization rates also increase which may result in an increase in traffic fatality. Eventually, as per capita income passes a certain threshold, several factors come into play which

may slow a growth in negative externality. This might be explained by the fully-developed roadway infrastructures, pedestrian walkways that separate walkers from motor vehicles, safety inspections of vehicles, seat belt requirements, regulations on alcohol consumption while driving, and effective enforcements of traffic laws and regulations. However, when it comes to the infrastructure development, Noland (2003) argues that the infrastructure improvements are not effective in reducing fatalities and injuries. Instead, the demographic changes in age cohorts, increased seat-belt use, reduced alcohol consumption and increases in medical technology may lead to the overall reductions in traffic fatalities.

Law et al. (2011) perform an empirical analysis of the Kuznets curve relationship between the economic growth, measured by per capita income, and traffic fatalities across 60 countries. The results show the presence of Kuznets curve relationship between per capita income and traffic fatalities, and study concludes that the medical and technology improvements has a significant effect in decreasing the number of traffic fatalities.

The negative consequences from the road accidents are regarded as socio-economic costs from the society's perspective. The cost estimates should then reflect the social utility of decreasing the number of fatal road traffic accidents. The costs per fatal injury are usually defined as direct (costs for health care, property damages and administration) and indirect costs (lost productive capacity) plus a value of safety per se (Trawen et al., 2002).

One of the important causes of traffic fatalities is speeding. Blows et al. (2005) argue that those who has reported frequently racing a motor vehicle for excitement or driving at 20 km/h or more over the speed limit, and those who has received the traffic convictions over the past 12 months, have been between two and four times more likely to be injured while driving over the same time. Driving unlicensed has been a risk factor for older but not younger drivers, and driving at 20 km/h or more above the speed limits has been a stronger risk factor for younger (<25 years) than older drivers.

Tarko (2009) proposes a new model of driver-preferred speeds derived from the assumption that drivers trade-off a portion of their safety for a time gain. The density of intersections, land development along the road, and the presence of sidewalks are the identified prominent risk perception factors. Moreover, the speed limit seems to encourage slow drivers to drive faster and fast drivers to drive slower.

The fraction of drivers driving under the alcohol influence is another leading cause of traffic fatalities. Drivers with alcohol in their blood are seven times more likely to cause a fatal crash, while legally drunk drivers pose a risk thirteen times greater than sober drivers (Levitt and Porter, 2001). Studying the effects of state alcohol policies on motor vehicle fatalities for children, Sen and Campbell (2010) find that the number of fatalities among the child motor vehicle occupants is strongly correlated with the alcohol use measured at the state level and that the administrative license revocation policies and the higher beer tax rates appear to consistently reduce such fatalities. For two of the three age groups, the beer tax rates are appeared to reduce fatalities during the night rather than the day. However, a zero tolerance and blood alcohol concentration limit laws do not seem to have any statistically significant effects on fatalities.

Islam and Mannering (2006) study the severity of accident injury with respect to differences in gender and age. Results show the increased likelihood of fatality for the young and middle-aged male drivers when they have passengers (which was not a significant factor for females); the increased likelihood of fatality for the young and older male drivers when driving the vehicles less than 5 years old (which was not a significant factor for females); the increased likelihood of injury for the middle-aged female drivers when driving vehicles aged 6 years and over (which was not a significant factor for males); and the increase in fatality likelihoods for the older males aged beyond 65 years (which was not a significant for females).

Simoncic (2001) shows that it is more likely that a severe injury or fatality can be the outcome of the traffic accident if the vehicle owner is aged 25 years or less compared to the case where the driver is older. This implies that the severity of accident consequences might be dependent on the drivers' age.

Analyzing the older road users' propensity to have accidents, Mori and Mizohata (1995) argue that the reduced physical and mental functions with the advancing age give improper driving characteristics to the elderly drivers, but are not deterministic factors of quitting the driving. Some elderly drivers who do not recognize or do not want to recognize the reduction in their physical condition may impose a risk of traffic accident. Probably, driving a vehicle supports their positive social activity and putting a restriction on their social activities by revoking a driving license might evoke the social concerns.

The risk of fatality is also different depending on the mode of travel. For instance, Beck et al. (2007) show that fatality rates are highest for the motorcyclists, pedestrians and cyclists, while the nonfatal injury rates are highest for the motorcyclists and cyclists. Elvik and Vaa (2004) compare the injury risks by mode of travel in six European countries. They calculate the injury rates per kilometer travelled and found that relative to the car occupants, pedestrians, bicyclists, and motorcyclists are at increased risk and bus occupants are at decreased risk. Simoncic (2001) also demonstrates that the pedestrians and motorcyclists are at higher risk than the cyclists.

Wong et al. (2009) identifying the groups that are at the fatality risk show that those aged over 60 years are as four times as likely to be pedestrian fatalities. Conversely, the risk of fatalities involving pedestrians and cyclists is reduced for males. However, males are at increased risk of fatalities involving the motorcyclists, scooter and pillion riders, whereas such risk is reduced for those aged 30 and over.

Clark and Cushing (2004) analyze the relationship between the population density and traffic fatality rates in urban and rural areas. The results show that the state population density is moderately strong predictor of rural but not urban traffic fatalities.

Hyatt et al. (2009) study the relationship between traffic fatalities and changes in gasoline prices. High gasoline prices decrease the number of traffic fatalities for automobiles but the fatality rate increases for motorcyclists. This suggests that the increase in the price of gasoline may induce car drivers to switch to the motorcycles as another mode of transportation. Grabowski and Morrisey (2004) show that a 10-cent increase in gasoline prices increases the motor vehicle fatalities by 2.3% over a 2-year period. By the same token, Wilson et al. (2009) argue that rising the gasoline prices may result in over 1500 additional motorcycle fatalities annually for each dollar increase in the gasoline prices.

Wenzel and Ross (2005) study the influence of a vehicle type and vehicle model on traffic fatalities. Authors find that most car models are as safe to their drivers as most sport utility vehicles (SUV). However, the SUV and pickup trucks impose higher fatality risk on the drivers of other vehicle types, and this fatality risk increases with the vehicle size.

Lam (2003) investigates the risk patterns of the drivers with different license status. The results indicate that females are at higher risk of being died or injured in a traffic accident than males. If not controlling for the driving experience and ages, the main cause for accidents are drivers' own behaviors and driving conditions. Special road features increase the risk of an accident injury for drivers with a learner and provisional license status. Alcohol has an impact on the fully licensed drivers aged 18-24 years.

3 Passenger car traffic performance in Sweden

A high level of economic development and quality of life contributes to the increase in motorization rate in Sweden. Between 1992 and 2009, the rate of motorization has increased from 487 vehicles[2] to 565 vehicles per 1000 inhabitants (Fig. 3.1). The rate of motorization has decreased by 3.30% during 1992-1994, and sharply increased by 15.15% during 1995-2000. In general, the rate of motorization is rising, and during the last 18 years the increase was 16.17%.

The increasing rate of motorization leads to a higher level of externalities in the form of air pollution, noise, road congestion, traffic accidents etc. For instance, the accident rate has increased from 179 to 200 per 100 000 inhabitants during the period from 1992 to 2009 (Fig. 3.2). As the figure shows, a relatively stable accident rate is observed during 1992-2001, while a sudden increase by 15.4% occurs between 2001-2003 and remains stable in the subsequent years. Overall, the traffic accident rate has on average increased by 11.58% during 1992 and 2009.

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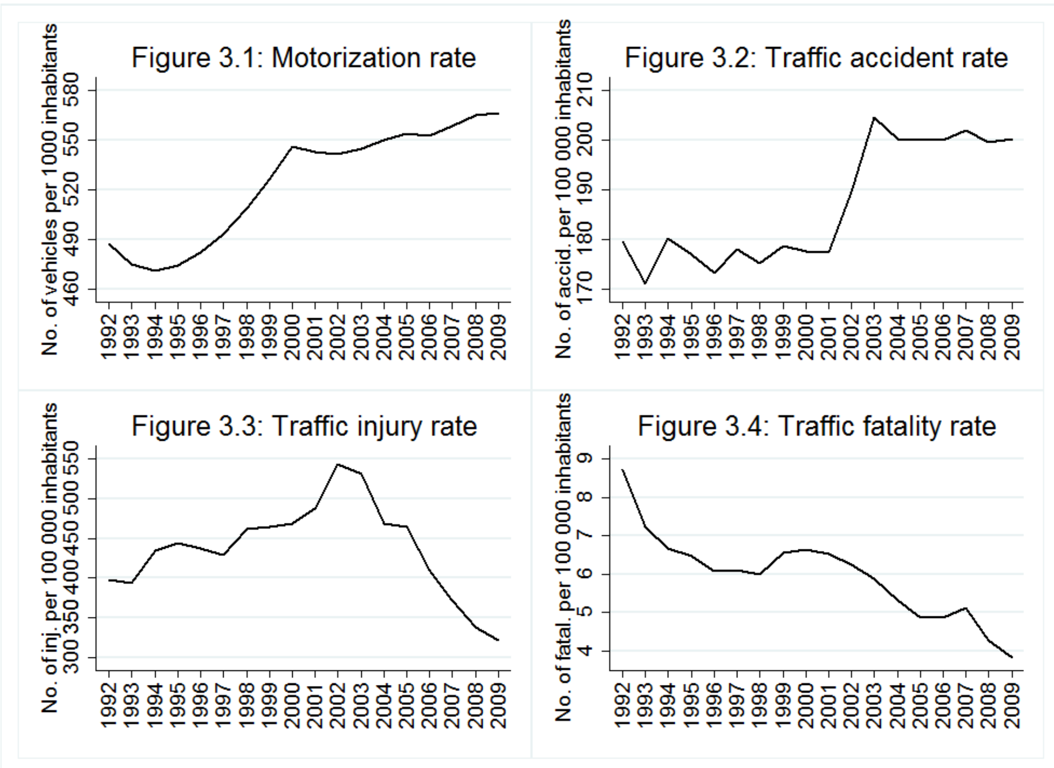
[2] Henceforth, the passenger cars are denoted as vehicles.

The consequences of traffic accidents are illustrated by the rate of injuries and fatalities that occurred on the road. With the slight fluctuations, the number of injuries has been increasing until 2002, resulting in 543 traffic injuries per 100 000 individuals (Fig. 3.3). Thereafter, there is a drastic decrease by 41% between 2003 and 2009.

The number of traffic fatalities has been decreasing until 1998, afterwards, there was an increase by 10.8 and 5.5% during 1999-2000 and 2005-2007, respectively (Fig. 3.4). In general, the rate of fatalities is decreasing, and during 1992 and 2009 a decline in traffic fatalities became 56.12%. Note that despite the increase in the motorization and accident rates, the rates of traffic injuries and fatalities are decreasing.



In 1997, Sweden has adopted a policy of Vision Zero which became the foundation for road safety operations in the country. The objective of the policy is that no one should be killed or seriously injured in the road traffic. Road traffic is a complex system consisting of different components such as the roads, vehicles and road users, where a constructive interaction among them is essential to ensure the traffic safety. The obvious result of the Vision Zero is the change in the road environments in Sweden. The central median barriers and roundabouts have become much more common, as have different types of speed reducing measures in the built-up areas. The results achieved so far indicate the evidence of a reduction in the number of traffic fatalities in the recent years, though the traffic is increasing (Vägverket, 2006). This can be explained by the realization of the road safety measures developed by the national road safety research institutions. For instance, Elvik et al. (2009) discuss the benefits of road safety research in Sweden. Authors conclude that the outcomes of the road safety research serve for the benefit of society, and these benefits by a wide margin outweigh the cost of the research.

4 Model

To analyze the impact of various socio-economic factors on the traffic fatality rate, we use a multiple regression model that considers the income level, population, vehicle park size, unemployment rate, traffic offence, fuel price and time trend to explain the incidence of traffic fatalities.
This implies that the general relationship is represented by the following equation:

$$\ln(FATAL_t) = \beta_0 + \beta_1 \ln(INC_t) + \beta_2 \ln(POP_t) + \beta_3 \ln(VEHP_t) + \beta_4 \ln(TROFF_t) + \\ + \beta_5 FUEL_t + \beta_6 UNEMP_t + \beta_7 TREND + \varepsilon_t$$

The dependent variable *FATAL* represents the annual number of deaths that occurred on the road; *INC*- the annual income level; *POP*- the amount of population; *VEHP* – the size of the vehicle park; *TROFF*- the amount of traffic offence; *FUEL* – a fuel price; *UNEMP*- the rate of unemployment; *TREND*- a time trend variable. To facilitate the interpretation of the coefficient estimates, the variables income, population, vehicle size and traffic offence are log transformed.
Before estimating a traffic fatality model presented above, we need to conduct two diagnostic tests. The first one is a unit root test which is used to examine whether the variables in the model are stationary or not. The testing procedure requires the identification of the nature of nonstationarity, which is thoroughly discussed in the next section. The accuracy in conducting this test is important, since the consequences of using nonstationary time series are unreliable coefficient estimates from the least square estimator, test statistics and predictions. Some studies underprioritize the importance of this test, which leads to the problem of spurious regression (Wooldridge, 2013; Hill et al., 2001).
The second test is a multicollinearity test where the strength of a relationship between explanatory variables is examined. If correlation between two variables is too high (larger than 0.7), the individual impact of variables becomes difficult to identify. In that case, one of the highly correlated variables should be dropped.
Based on the results of a unit root and multicollinearity tests, we modify our traffic fatality model.

5 Data

The sample consists of annual data over the period from 1992 to 2009. The study is performed on the example of Sweden, and the vehicles considered are passenger cars, so that the trucks, tractors, busses, motorcycles etc. are excluded. The data are constructed from traffic fatality rate, income level, population, vehicle park size, unemployment rate, traffic offence and fuel price. The sources of the data are the Statistics Sweden, the Swedish Insurance Federation, the Transport Analysis, Bil Sweden, the Swedish Transport Agency, the Swedish Petroleum Institute, and the Swedish Institute of Public Health.

A description of the explanatory variables and their expected impact on a traffic fatality rate is discussed below.

The income level of a country is reflected by its GDP per capita, the Swedish crowns (SEK), current prices. An increase in income level would increase the demand for safety and consumption activity. A rise in income level increases the probability of an accident due to accessibility of using a vehicle, but the probability of fatality from an accident would decline because of the increase in demand for safety (Peltzman, 1975; Zlatoper, 1989, 1991). Therefore, it is expected that the income level variable (*INC*) is positive.

The amount of population with driving licenses might have a direct influence on traffic fatality. The proportion of young drivers possessing a driving license between the ages of 18 and 24 has the highest accident rates than other age groups. The nature of the group specific accident rates shows that accident rates are highest for the youngest drivers, decline with age, then rise for the older drivers. This can be explained by the younger drivers' greater risk-taking behavior and elderly drivers' declining physical capabilities (Anbarci et al., 2006). Therefore, we include two variables to account for the young driver groups aged 18-24 (*POP1*), and elderly driver group aged 66 and over (*POP2*). To note, compared with many previous studies that use the general age-classified population data, we have an access to more detailed data on the number of issued driving licenses categorized by age, so that it would be possible to encompass the group that potentially causes traffic accidents. Furthermore, we admit that drivers may have different categories of driving licenses (A, B, C etc.). However, as current study focuses on the passenger cars only, we have proxied these variables by the number of drivers that has a B-category driving license. It is expected that the traffic fatality rates are positively associated with these two age groups.

According to the Swedish legislation, every registered vehicle in Sweden can have the status of being either an active-license or inactive-license vehicle. To use a vehicle in traffic, it must have a status of active-license vehicle, which implies that driver must pay for vehicle insurance and tax. Before cancelling a system for the vehicle control stickers on January 1st, 2010, it was possible to visually identify the status of a vehicle via a control sticker on the registration plate. A control sticker has previously indicated that vehicle has a valid insurance, paid a vehicle tax and passed a safety inspection. This implies that, without a regular police control, it will be difficult to visually identify whether a vehicle in traffic has an active or inactive license. Nevertheless, in accounting for the vehicle park size in traffic, we include only the active-license vehicles. It is expected that this variable (*VEHP*) is positively associated with traffic fatality since more vehicles in traffic increases the probability of an accident.

As unemployment level increases, the economic condition of an individual worsens which may decrease affordability of owning and driving a vehicle. The less reliance on a vehicle usage should decrease the probability of traffic fatalities. These arguments are in line with the evidences from Partyka (1984), Evans and Graham (1988) and Welki and Zlatoper (2007). Therefore, the unemployment rate variable (*UNEMP*), measured in percentage, is expected to have a negative relationship with traffic fatalities.

Road safety requirements adopted via legislations may contribute to a safer driving. Under the safety requirements we imply enforcing the speed limit, alcohol intoxication while driving, seat belt law etc. The enforcement of laws should reduce the number of traffic accidents, and hence fatalities on the road. As the enforcement measures, Welki and Zlatoper (2007) use the arrests for speeding, arrests for not wearing seat belts and arrests for drunk driving. We proxy these traffic offences with the number of revoked driving licenses due to the speeding (*TROFF1*) and drunk driving (*TROFF2*). It is expected that strengthening the law enforcement would reduce traffic fatalities.

High gasoline prices may lead to a decline in demand for vehicle use, which may decrease the probability of traffic accident, and hence fatalities. However, an increase in the price of gasoline may induce the vehicle drivers to switch to the motorcycles as an alternative mode of transportation, so that there might be a decrease in the number of fatalities for passenger cars but the fatality rate might increase for motorcyclists (Hyatt et al., 2009; Grabowski and Morrisey, 2004). The average price of 95 octane gasoline is used to account for the fuel price (*FUEL*), SEK, current prices. It is expected that the effect of the changes in fuel price is uncertain a priori.

Certain unmeasured, thus omitted effects that are not in the model are expected to improve the traffic safety over time. These effects might be the state of driver skill, quality of highway, private demand and supply of the improved vehicle design, quality of the health care, technical advancement in vehicle maintenance etc. (Peltzman, 1975). To account for the above described effects, a time trend variable (*TREND*) is included in the model, which equals one in year 1992 and increases by a year in the subsequent years. Many studies have shown a negative and significant association between a trend variable and traffic fatality rate, implying that these effects are causing a downward trend in traffic fatalities over time (Peltzman, 1975; Crandall and Graham, 1984; Welki and Zlatoper, 2007; Law et al., 2011). Therefore, it is expected that the impact of trend on traffic fatalities would be negative.

5.1 Descriptive statistics

Descriptive statistics are presented in Table 5.1. According to the table, the average number of annual traffic fatalities is about 533. The mean income level is 260168 SEK per capita, while he average number of vehicle in traffic is 3936651. The mean proportion of population possessing driving license is 462757 and 893310, for young and old drivers respectively. As we may note, the proportion of elderly drivers is as twice large as younger drivers. The average number of revoked driving licenses due to the speeding and drunk driving are 16549 and 7007, respectively. It seems that the prevailing reason for driving license revocations is the speeding offence. Finally, the average price of gasoline is SEK 9.4, and the mean rate of unemployment during 17 years is 7.21%.

Table 5.1: Descriptive statistics (1992–2009)

	Mean	Std. deviation	Min	Max
Traffic fatality	533.1	92.8	358	759
Income level	260168.3	56668.6	179506	348566
Vehicle park size	3936651	262453.7	3566040	4300752
Population aged 18-24	462757.2	47731.3	410358	563328
Population aged 67 and over	893310.4	115065.3	704453	1116539
Traffic offence: speeding	16549.2	2527.7	12051	20471
Traffic offence: drunk driving	7007.8	1371.6	4941	10193
Fuel price	9.3	18.2	6.3	12.5
Unemployment	7.2	1.7	4.8	9.8

6 Results

This section presents the results of unit root and multicollinearity tests. Afterwards, based on the results of these tests, we specify several models and provide the corresponding estimation results.

6.1 Unit root test

According to the visual inspection (Appendix 1), the distribution of variables appears to be dissimilar, thus the models for testing a unit root are specified individually for each variable.

Traffic fatality shows a trend and follows a random walk with downward drift (Fig A.1), thus the corresponding model is:

$$\Delta y_t = \alpha_0 + \theta y_{t-1} + \nu_t \qquad (6.1.1)$$

where, $\Delta y_t = y_t - y_{t-1}$ is the first difference of time series, α_0 is an intercept,

y_{t-1} is a lag (first) of variable, v_t is a random disturbance with mean zero and constant variance σ_v^2.

Income level, population of old drivers, vehicle park and fuel price grow over time exhibiting a time trend (Fig.A.2), therefore the appropriate testing model is:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \theta y_{t-1} + v_t \qquad (6.1.2)$$

where, *t* is a time trend.

Population of young drivers, traffic offences for speeding and drunk driving, as well as unemployment rate exhibit no definite trend and follows a random walk (Fig. A.3), thus the model for testing a unit root is[3]:

$$\Delta y_t = \theta y_{t-1} + v_t \qquad (6.1.3)$$

The stationarity requires the condition where in all above presented equations $|\theta| < 0$, otherwise the time series are said to be nonstationary.

We test $H_0 : \theta = 0$ against $H_1 : \theta < 0$. At $\alpha\%$ significance level, the null hypothesis of a unit root is rejected if $\tau = \frac{\hat{\theta}}{se(\hat{\theta})} < DF_c$, where DF_c a critical value for the Dickey-Fuller test.

The unit root test results are presented in Table 6.1, which suggest that the traffic fatality rate is integrated of order zero ($\ln(FATAL_t) \sim \mathrm{I}(0)$), i.e. stationary, whereas other variables are nonstationary. By taking the first differences of nonstationary time series, we obtain stationary variables and then use in the model estimation.

Table 6.1: Regression results of a unit root test

	Coefficient	Std. error	τ-statistic	5% critical value
Traffic fatality	-0.0945	0.1191	-0.794	-1.753
Income level	-0.4137	0.5336	-0.775	-3.600
Vehicle park size	-0.2816	0.1854	-1.519	-3.600
Population aged 18-24	-0.0007	0.0006	-1.132	-1.950
Population aged 67 and over	-0.2305	0.1753	-1.314	-3.600
Traffic offence: speeding	0.0001	0.0031	0.047	-1.950
Traffic offence: drunk driving	-0.0019	0.0024	-0.794	-1.950
Fuel price	-0.7507	0.2547	-2.947	-3.600
Unemployment	0.0066	0.0449	0.146	-1.950

[3] See Wooldridge (2013), Hill et al. (2001) and Gujarati (2004).

6.2 Multicollinearity test

A correlation matrix for the explanatory variables is presented in Table 6.2. Note that a trend variable is highly correlated with the variable for young population (0.89) and unemployment rate is highly correlated with vehicle park (0.78) and income level (0.72). Therefore, some of these variables should be excluded from the model.

Table 6.2: Correlation matrix

	POP1	POP2	VEHP	TRO FF1	TRO FF2	INC	FUEL	UNE MP	TRE ND
POP1	1								
POP2	0.06	1							
VEHP	-0.30	-0.48	1						
TROFF1	0.15	-0.40	0.21	1					
TROFF2	0.58	-0.18	-0.05	0.32	1				
INC	-0.41	-0.45	0.53	0.05	-0.28	1			
FUEL	-0.06	-0.16	-0.07	0.02	0.07	0.05	1		
UNEMP	0.23	0.36	-0.78	-0.12	0.08	-0.7	0.28	1	
TREND	0.89	0.01	0.01	0.12	0.65	-0.3	-0.09	-0.03	1

6.3 Multiple regressions

Considering the results of the unit root and multicollinearity tests, several model specifications are considered.

Model A

$$\ln(FATAL_t) = \beta_0 + \beta_1 \Delta \ln(INC_t) + \beta_2 \Delta \ln(POP2_t) + \beta_3 \Delta \ln(VEHP_t) + \beta_4 \Delta \ln(TROFF1_t) + \\ + \beta_5 \Delta \ln(TROFF2_t) + \beta_6 \Delta FUEL_t + \beta_7 TREND + \varepsilon_t$$

In this model specification, the variables for young population and unemployment are excluded, due to the strong correlation between the variables for: young population and time trend; unemployment rate and income level; unemployment rate and vehicle park.

Model B

$$\ln(FATAL_t) = \beta_0 + \beta_1 \Delta \ln(POP2_t) + \beta_2 \Delta UNEMP_t + \beta_3 \Delta \ln(TROFF1_t) + \beta_4 \Delta \ln(TROFF2_t) + \\ + \beta_5 \Delta FUEL_t + \beta_6 TREND + \varepsilon_t$$

In this model, the excluded regressors in Model A are now included instead of the income level and vehicle park, i.e. the unemployment rate is included in this model, while the income level, young population and vehicle park are excluded.

Model C

$$\ln(FATAL_t) = \beta_0 + \beta_1 \Delta \ln(INC_t) + \beta_2 \Delta \ln(POP1_t) + \beta_3 \Delta \ln(POP2_t) + \beta_4 \Delta \ln(VEHP_t) + \\ + \beta_5 \Delta \ln(TROFF1_t) + \beta_6 \Delta \ln(TROFF2_t) + \beta_7 \Delta FUEL_t + \varepsilon_t$$

Unemployment rate and trend variables are excluded in this model, due to the high correlation between the variables for: young population and time trend; unemployment rate and income level; unemployment rate and vehicle park.

Model D

$$\ln(FATAL_t) = \beta_0 + \beta_1 \Delta \ln(POP1_t) + \beta_2 \Delta \ln(POP2_t) + \beta_3 \Delta UNEMP_t + \beta_4 \Delta \ln(TROFF1_t) + \\ + \beta_5 \Delta \ln(TROFF2_t) + \beta_6 \Delta FUEL_t + \varepsilon_t$$

Income level and vehicle park are replaced with unemployment rate, while a trend variable is replaced with the young population variable due to the high correlation. Regression estimates of the above specified models are presented in Table 6.3.

Table 6.3: Regression results of traffic fatality models

	Model A	Model B	Model C	Model D
Income level	1.624*** (0.786)		1.933 (1.153)	
Population aged 18-24			-4.328* (0.928)	-4.131* (1.107)
Population aged 67 and over	-1.151 (1.915)	-1.271 (1.712)	-2.785 (2.821)	-2.602 (3.191)
Vehicle park size	-1.084 (2.289)		-8.159** (3.404)	
Traffic offence: speeding	0.161 (0.137)	0.134 (0.132)	0.310 (0.201)	0.260 (0.248)
Traffic offence: drunk driving	0.626** (0.248)	0.633** (0.239)	0.272 (0.336)	0.119 (0.409)
Fuel price	<-0.001 (0.000)	<0.001 (0.000)	<-0.001 (0.000)	<0.001 (0.000)
Unemployment		-0.026*** (0.013)		0.009 (0.024)
Trend	-0.031* (0.004)	-0.034* (0.004)		
Constant	6.552* (0.086)	6.627* (0.062)	6.303* (0.112)	6.277* (0.096)
Adjusted R^2	0.854	0.861	0.681	0.509
AIC	- 42.352	- 43.455	- 29.092	-21.961

***, **, * Significant at 1%, 5% and 10%, respectively. Standard errors are in parentheses.

A choice of the model specification among four alternatives might be based on the *Adjusted R-squared*, where a model with the highest value is selected, i.e. *Model B* should be preferred. Another formal criterion to select a model is Akaike's Information Criterion (AIC), where a model with the lowest AIC should be selected. The AIC values for four models suggest the selection of *Model B*, therefore this model is used to explain the incidence of traffic fatalities.
Estimation results for *Model B* (only statistically significant coefficient estimates are discussed) suggest that a 10% increase in driving license revocations due to the drunk driving increases traffic fatalities by 6.3%, all else equal. An increase in unemployment rate by 1% leads to a decrease in traffic fatalities by 0.026%. A trend variable suggests that the annual improvement of driving skill, vehicle design, highway quality, health care quality and other institutional road safety measures decrease traffic fatalities by 0.03%.

6.4 Result discussion

A unit root test indicates that the traffic fatality rate is stationary time series that follows a random walk with downward drift, while the other variables are differenced to turn them into stationary time series.
A multicollinearity test of explanatory variables shows that a time trend variable is highly correlated with a variable for young population aged 18-24 who has a driving license. It is also revealed that the unemployment rate has a strong correlation with the vehicle park and income level variables.
Taking into account the results of the unit root and multicollinearity tests, four models are specified. In constructing these models, we exclude highly correlated regressors and replace the level (nonstationary) variables with their first differences.
A choice of the model is based on the values of the adjusted R-squared and AIC, where the selected model is constructed from such variables as the population of elderly drivers, unemployment rate, traffic offences due to the speeding and drunk driving, fuel price and time trend to explain the incidence of traffic fatalities.
Results indicate that an increase in driving license revocations due to the drunk driving increases traffic fatalities. The expectation was that driving license revocations should decrease the number of fatalities on the road by expelling the drivers that violate the traffic safety laws, especially, when the cause of infringement is alcohol intoxication[4]. However, Welki and Zlatoper (2007) find a similar result and argue that after fatal accidents, police may enforce the traffic safety regulation more strictly. Our data support this argument, i.e. a sudden increase in the number of traffic fatalities (9.23%) in 1999 is followed a year later by a sharp increase in the number of driving license revocations due to the drunk driving (11.68%). This implies that after traffic accidents, police undertake safety

[4] Sen and Campbell (2010) find that administrative license revocation policies reduce traffic fatalities.

measures by exerting more stringent control on the roads.
Another finding indicates that an increase in unemployment rate is associated with a decline in traffic fatalities. Worsening of the purchasing power due to the increased unemployment rate has the negative influence on vehicle ownership. Consequently, fewer vehicles in traffic decreases the probability of traffic fatalities. This result is consistent with Partyka (1984), Evans and Graham (1988), as well as Welki and Zlatoper (2007).
Moreover, we also find that there are some unmeasured factors that improve traffic safety over time. The factors that contribute to the decline in traffic fatality rate might be the improvement of driving skill, vehicle design, highway quality, medical care and other traffic safety measures, which are in line with the findings of Peltzman (1975), Crandall and Graham (1984), Welki and Zlatoper (2007) and Law et al. (2011).

7 Conclusion

This study empirically analyzes the incidence of road traffic accidents in Sweden from the perspective of different socio-economic factors. In the presence of the varying performance of road traffic systems in different countries and conflicting findings of previous research, the purpose of this study is to determine the socio-economic factors that may explain the incidence of traffic fatalities.
Analysis uses the Swedish annual data over the period from 1992 to 2009, where a traffic fatality rate is modelled as a function of population of elderly drivers, traffic offence due to the drunk driving, unemployment rate, fuel price and time trend. After conducting a unit root and multicollinearity tests, a traffic fatality model is constructed. We find that an increase in driving license revocations due to the drunk driving increases traffic fatalities. Despite the common belief that more revocations should decrease the number of traffic fatalities, our result suggests the opposite. This might be explained by strengthening the control by police as a consequence of the past fatal accidents. Moreover, worsening of the economic situation due to an increase in unemployment rate contributes to a reduction in traffic fatality rate. Finally, some unmeasured factors such as the improved driving skill, vehicle design, highway quality, medical care and other traffic safety measures significantly decrease traffic fatalities.
Results of this study are in line with other findings in the literature, and our empirical study investigated the incidence of traffic accidents associated with fatality based on aggregate data, whereas a separate analysis for specific groups on micro level data might shed a better light to the investigated issue which would serve as a reason for further research.
This research distinguishes itself from the previous studies in three respects. Many time series studies addressing the issue of traffic fatalities do not mention or recognize the potential problem of nonstationarity. Present study investigates the nature of nonstationarity of the variables and parsimoniously specifies a model for

each variable to test for unit roots to avoid the problem of spurious regressions. Moreover, we use several variables that are newly introduced by recent studies in traffic safety literature. Furthermore, this is the first study analyzing the impact of socio-economic factors on traffic fatality rate for the case of Sweden.

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Appendix

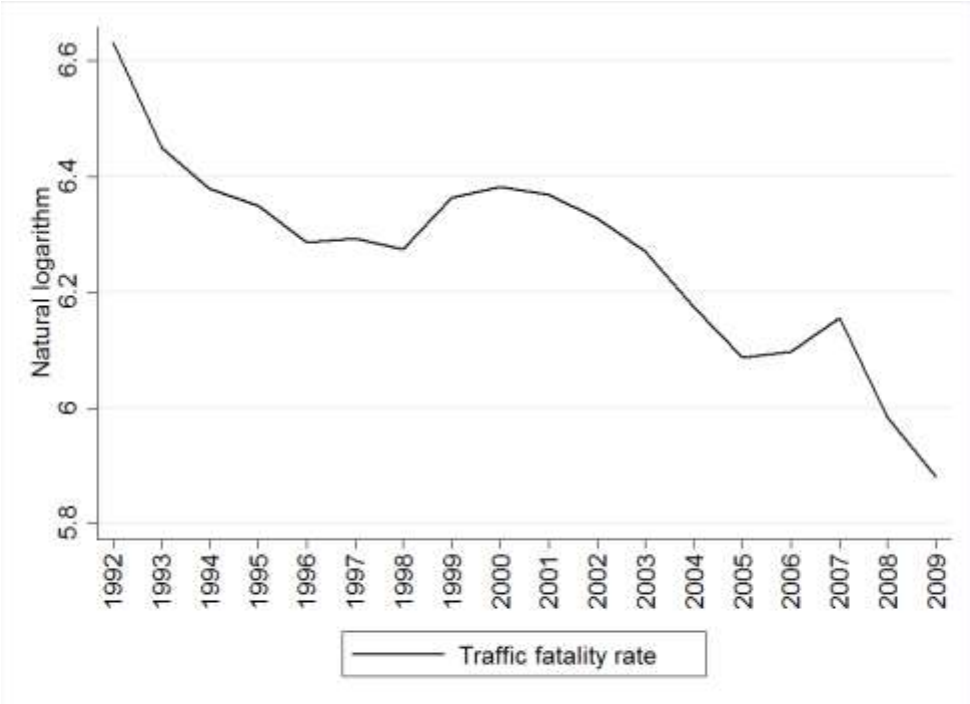

Figure A.1: Economic time series: a random walk with drift

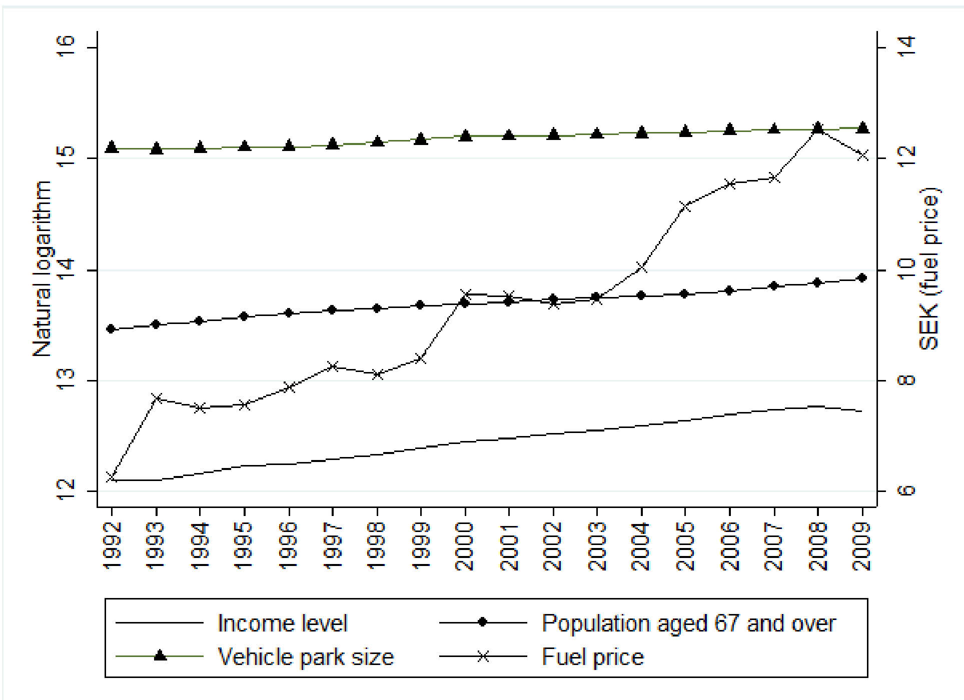

Figure A.2: Economic time series: a time trend

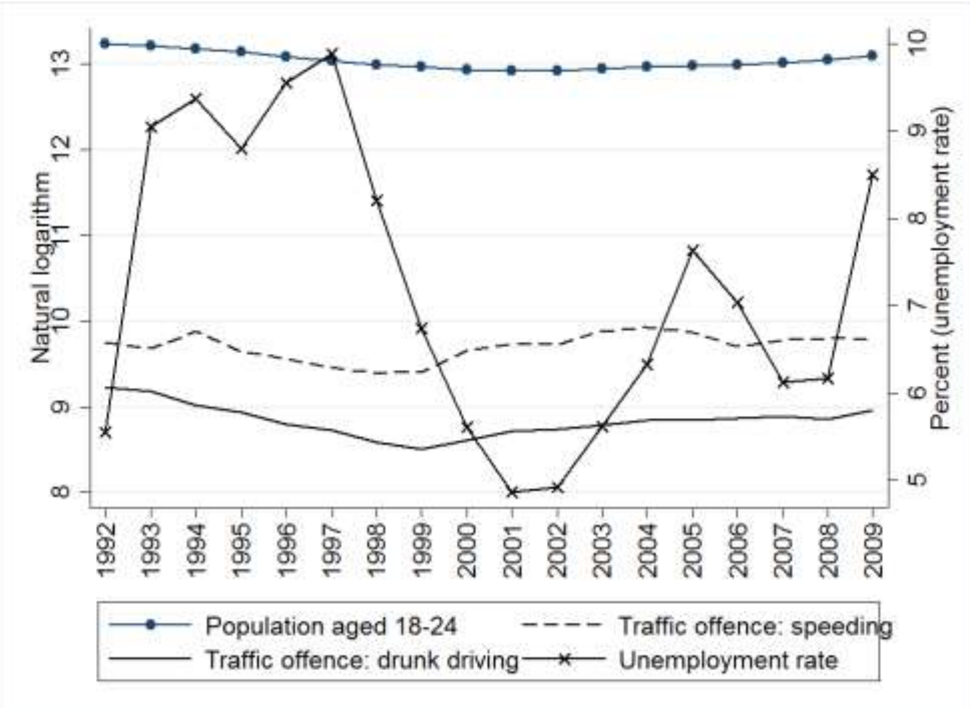

Figure A.3: Economic time series: a random walk