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Socio-economic determinants of road traffic accident fatalities in low and middle income countries

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Abstract

In low and middle income countries road traffic accident fatalities will become in the near future one of the three major causes of death. Given that in particular the active population accounts for these fatalities, the potential economic implications are large, on the micro and the macro level. Yet, so far not much is known about the determinants and economic consequences of low road safety, in particular about the factors influencing road users' behavior. Obviously this makes the design of interventions to prevent road traffic accidents and to care for the victims a serious challenge. The objective of this note is to summarize and review the existing knowledge on the determinants of road traffic accident fatalities, to identify the relevant research gaps in particular for low and middle income countries and to suggest ways to collect data and to conduct experiments that help to close these gaps. We also present a cross-country analysis of the determinants of road traffic accident fatalities that takes into account a wide range of potential environmental, economic and social factors.

JEL Classification: I10, O10, O57

Keywords

Road safety, driving behavior, vulnerable road users, causes of death

1 Introduction

The World Health Organization (WHO) estimates that road traffic crashes cause over 1.2 million deaths and probably more than 25 million severe injuries per year. Moreover, the WHO's *Global Status Report on Road Safety* states that over 90% of the world's fatalities on the roads occur in low and middle income countries, although these countries only have about 48% of the world's registered vehicles. The WHO anticipates, unless immediate action is taken, that over the next 15 years, the number of people dying annually in road traffic crashes may rise to 2.4 million. The increase will probably entirely occur in low and middle income countries and road traffic injuries will become there one of the three major causes of death. Globally, road traffic injuries are already today among the three major causes of death for the age group 5 to 44 years (WHO, 2009).

Given these numbers, road traffic injuries have to be seen in low and middle income countries as one of the most important health problems along with diseases such diarrhoea, malaria, HIV/AIDS and tuberculosis. Road traffic injuries may also entail major economic problems, in particular, because they affect, as does HIV/AIDS, first of all the economic active population. Providing medical services to those injured may imply a high burden on national health systems and budgets. Hence, not surprisingly the WHO estimates that global losses due to road traffic injuries are probably close to US$ 518 billion and are likely to cost governments between 1% and 3% of their GDP (Ansari, Akhdar, Mandoorah *et al.*, 2000; Jacobs, Aeron-Thomas and Astrop, 2000; WHO, 2009).[1] In many low income countries this is obviously more than the total amount that these countries receive in terms of development assistance.

Households will not only be affected emotionally, but may also have serious problems to cope economically with such health shocks. Medical costs, funeral expenses and a loss of an active household member may have serious and lasting implications for disposable household income.[2] Moreover, different studies suggest that nearly half of those dying on the road are vulnerable road users –i.e. pedestrians, cyclists, and those using motorized two or three-wheelers– as well as users of unsafe public transportation (WHO, 2009). It is likely that these people rather belong to groups of lower socio-economic status (although probably not to the poorest of the poor). Research from Bangalore, for instance, found that mortality from road traffic injuries was 13.1 and 48.1 per 100,000 in the poorer socio-economic groups of urban and rural populations respectively, compared to 7.8 and 26.1 per 100,000 among their more affluent urban and rural counterparts

[1] Ansari *et al.* (2000) report for instance that in Saudi-Arabia the impact of road traffic crashes on the health budget is dramatic; at any time one third of beds in public hospitals would be occupied by road traffic crash victims.

[2] Indeed Deaton (2003) speculates that "in agricultural villages around the world, the poorest people are often those who cannot work as a result of some long-term disability or injury."

(Aeron-Thomas, Jacobs, Sexton *et al.*, 2004).[3] Hence, if vulnerable road users are also economically vulnerable, road traffic crashes may also imply important (income) distributional consequences.

In order to understand the causes and consequences of road traffic crashes and to design appropriate policy interventions to reduce their number, more research is needed in this area. So far most studies just analyze aggregated data on patterns and trends without investigating the underlying causal relationships. Moreover, lack of data, data harmonization and a common terminology hamper research in particular in middle and low income countries. The fact that road traffic crashes are in most poorer countries not yet recognized as a major health problem can further explain the little effort made so far to understand the problems and to collect the necessary data.

Many reports and studies, mostly based on experiences in richer countries, suggest that road infrastructure (e.g. separate tracks for pedestrians and two-wheelers), speed-limits, drink-driving laws, laws prescribing the use of helmets, seat belts and child restraints and, of course, mechanisms to enforce all these rules can be effective means to reduce the incidence of road traffic fatalities. However, these studies are limited in their use because they usually rely on observational data, they only exploit cross-country variation and their results are probably only hardly transferable to middle and low income countries.

Good evidence-based policy advice should rely on experimental or quasi-experimental data. Research should aim to explain within country variation in driving behavior and investigate how different groups respond to different laws and different modes of enforcement. Surprisingly only few studies so far have examined the individual and social determinants of driving behavior.[4] Yet, observing that in poorer countries taxi drivers behave particularly risky is, at least theoretically, not straightforward to explain. On the one hand it might be that they are pressed by time in order to earn the necessary return, but on the other hand most taxi drivers are not protected by any insurance and may easily loose through risky actions their entire physical (and human) capital. Research should find out whether driving behavior is also shaped by cultural attitudes[5] and whether it depends on parameters such as life expectancy and differences in discount rates. Again, individual data may help to answer this kind of questions.

Research may also investigate to what extent awareness campaigns should complement laws and legislation to highlight the safety benefits of complying with the legislation and to increase the perception of being detected and penalized when not complying with the law. Eventually, successful enforcement also requires to explore appropriate incentive schemes, that make it likely that police

[3] According to the authors the prevalence of road traffic injuries is higher in rural areas than in urban areas, because the surveyed rural areas are rapidly motorizing.

[4] Exceptions are Fosgerau (2005); Factor, Mahalel and Yair (2008)

[5] Some taxi drivers in Delhi, India, for instance, told us that for them driving is ‘competition’.

officers and other bureaucrats resist corruption.[6] A research gap exists also on the side of the victims. The design of effective interventions in this area needs knowledge about the profile of victims, the problems they face and how they try to cope with such shocks.

The objective of this note is to summarize and review the existing knowledge on the determinants of road traffic fatalities, to identify relevant research gaps in particular for middle and low income countries and to suggest ways to collect data and to run experiments that help to close these gaps. Thus this note has a purely exploratory character and definitely raises more questions than it answers — this is on purpose.

The remainder of this paper is organized as follows. In Section 2 we review the literature that deals with the determinants of road traffic fatalities on the macro and individual level. We will also briefly discuss theoretical approaches that were initially developed for other problems, but of which we think that they might be useful to conceptualize at least part of the questions raised above. In Section 3 we discuss available data sources on road traffic crashes including their strengths and shortcomings in helping to understand the problems at stake. In Section 4 we use a cross section of countries and aggregated data on the incidence of traffic fatalities as well as a smaller panel data set of countries to explore the role of income and other factors including selected proxies of driving behavior in explaining such fatalities. Given the substantial differences in data quality across richer and poorer countries we undertake this exercise separately for different country samples. In Section 5, we discuss what we think are the major gaps to be filled and make suggestions on experiments that would help to collect the appropriate data. Section 6 concludes.

2 Literature review

An increasing number of published studies on road traffic injuries and fatalities shows that this problem gets more and more attention by governments, NGOs, academics and the international community more broadly. Good practices manuals[7], assessments of the frequency and determinants of road traffic injuries and fatalities[8] as well as studies documenting success stories of policy interventions in several developing countries have been published and disseminated to help low and middle income countries to take action against the problem. However, rigorous evidence on which policy interventions could be based are still relatively

[6]The *Global Status Report*, for instance, reports that 29% of all countries meet basic criteria for reducing speed in urban areas, but that in only 10% the enforcement of speed limits is effective (WHO, 2009). Corruption may be one reason for such low enforcement levels. Another may of course be rooted in the costs of enforcement.

[7]See e.g. published by the Global Road Safety Partnership.

[8]See e.g. the Regional Health Forum of South East Asia of 2004 or the WHO Global Status Report on Road Safety of 2009.

scarce. In what follows we provide a short review of what we find are important contributions in this domain. The choice is of course subjective and limited, given the length of this paper.

2.1 Cross-country studies

Quite a large number of the existing studies are first of all interested to explore the link between income and road traffic fatalities at a cross-country level (see e.g. Wintermute, 1985; Jacobs and Cutting, 1986; Söderland and Zwi, 1995; Van Beeck, Borsboom and Mackenbach, 2000; Kopits and Cropper, 2005; Anbarci, Escaleras and Register, 2006; Bishai, Quresh, James *et al.*, 2006; Paulozzi, Ryan, Espitia-Hardeman *et al.*, 2007). They more or less all find that at very low levels of income road traffic fatalities per (100,000) person(s) increase with income (because motorization goes up) up to a certain threshold, after which countries seem to be able to invest in safety measures (including safer cars) and possibly behavioral changes that bring traffic fatalities again down (e.g. separate tracks, preventive measures). This inverted U-shaped pattern first has been explicitly pointed out by Van Beeck *et al.* (2000). Kopits and Cropper (2005) tried, in addition, to relate traffic accidents to environmental externalities.[9] They suspect that the per capita income at which traffic fatalities begin to decline is in the range of incomes at which other externalities such as air pollution begin to decline as well. However, most of these studies offer surprisingly little discussion of how the income effect should be interpreted, for instance, whether this should be seen as a direct effect of income on road traffic crashes or whether income is first of all a proxy for the quality of the road network, the degree of motorization, the implementation and enforcement of safety measures and many other factors. Moreover, even after controlling for income, the residual is usually quite important. Indeed, Japan, for instance experiences a road mortality rate of 5.18 deaths per 100,000 inhabitants, while in the United States this rate is almost three times as high (13.94).[10] Van Beeck *et al.* (2000) highlight that Greece and Spain are cases with particular high fatality rates in Europe, even after income is controlled. Wintermute (1985), in an earlier study, emphasized that the analysis of road traffic crash fatalities need to account for a much broader set of determinants than just income. He mentions determinants such as geography, rules and regulations, urbanization, nature of traffic mix, infrastructure development, availability of medical services and culture, but does not examine these empirically.

Yet a few studies do indeed analyze the conditional and unconditional effect of income by including in their analysis additional determinants of this type (Jacobs and Cutting (1986); Söderland and Zwi (1995); Anbarci *et al.* (2006); and Bishai

[9] See e.g. Grossman and Krueger (1995).
[10] See WHO Global Status Report on Road Safety, 2009, Table A.2.

et al. (2006)).

Jacobs and Cutting (1986) use a cross-sectional analysis to examine the link between fatality rates and social, economic and physical characteristics of selected developing countries. These include, besides GDP per capita, the number of circulating vehicles, road density (standardized by land size), vehicle density (per kilometer of road), population per physician and population per hospital bed. Their results show that fatality rates are not only related to GDP per capita, but also to vehicle density and population per hospital bed. Nevertheless, vehicle ownership is the only remaining statistically significant variable in a regression in which the effects of all these determinants are examined simultaneously. Using the fatality index (proportion of all persons injured that die) as the dependent variable, the only significant variable in the multiple regression analysis is population per physician (probably partly due to the limited sample size and multicollinearity problems).

Söderland and Zwi (1995), also perform a multiple regression analysis. They use data from 83 countries for the year 1990. As the dependent variable they consider alternatively the crude traffic-related death rate per 100,000 persons per year, traffic related deaths per 1,000 registered four-wheeled vehicles per year, the ratio of mid-age to total population mortality, the ratio of the male/female mortality rate and fatal injuries as a proportion of total injuries. They introduce different explanatory variables according to the outcome they analyze: number of vehicles per capita, road density (km of road per square km), total surface area, GDP per capita, health expenditure as percentage of GDP and population density. The authors find that GDP per capita is positively correlated with traffic-related deaths per 100,000 population, but negatively correlated with traffic deaths per 1,000 registered cars, suggesting that in per vehicle terms, income reduces road crash fatalities. Moreover, the number of road traffic accident related deaths among youth and elderly people is directly linked to population density. Finally, they show that GDP per capita and health expenditures as a share of GDP are associated with a declining rate of fatal injuries among road victims.

Bishai *et al.* (2006) have a particular focus on the *transmission channel* between income and road crashes. The authors use data from 41 countries for the period 1992 to 1996. Considered outcome variables include road traffic crashes, injuries, and fatalities. As channel variables they use the number of vehicles, kilometers of roadway, fuel consumption, alcohol consumption (available for a single year only), and population density. Fixed effects regressions were used to control for time-constant unobservable heterogeneity across countries. The authors find that with a GDP of \$1500 to \$8000 PPP per capita, controlling for the other variables, further national income growth does not bring about a further increase in road traffic crash fatalities, although the number of crashes and injuries continue to rise. Bishai *et al.* (2006) underlines that GDP has probably to be seen as a 'proxy' for a set of relevant but hard-to-measure factors such as urbanization, vehicle mix, road quality and health services. However, the authors do not investigate these channels further.

Finally, the last study we found which includes further determinants beyond income is Anbarci *et al.* (2006). They use a (unbalanced) cross country panel data set with in total 1,356 country-year observations for the period 1982-2000. This sample includes 23 countries from Africa, 12 from the Americas, 26 from Europe and 16 from Asia. The authors account for country-fixed and time-fixed effects and include as explanatory variables income, a corruption index, the illiteracy rate, the mortality rate (as a proxy for health care access), the number of four-wheeled motor vehicles in use per capita and various variables to capture the population structure. An interesting finding of this study is that corruption, as measured by the international country risk guide, significantly increases the occurrence of fatalities in relatively poor countries. The authors speculate that this happens via forged driving licences, low enforcement of rules and regulations as well as low vehicle maintenance and security.

Most of the papers cited above (see e.g. Söderland and Zwi, 1995; Van Beeck *et al.*, 2000; Kopits and Cropper, 2005; Anbarci *et al.*, 2006; Bishai *et al.*, 2006; Paulozzi *et al.*, 2007.) put particular emphasis on the finding of an inverted U-shaped relationship between the road traffic crash fatality rate and income per capita. This result is in these studies usually based on the unconditional relationship between fatalities and income. We show below that this relationship seems not to hold anymore if the partial correlation of income and fatalities is considered, i.e. controlling for the many others factors discussed above. Moreover, we find that the functional form of the relationship crucially depends on the number of very poor countries included in the sample.

2.2 Country specific studies

Other studies exploit the within-country variance in road traffic fatalities (see e.g. Garg and Hyder (2006), La Torre, Van Beeck, Quaranta *et al.* (2007), and Traynor (2008)). Traynor, for instance, analyzes the relationship between income and fatalities (per vehicle and miles traveled) across counties in the U.S. state of Ohio. He introduces various explanatory variables in addition to income such as population density, the incidence of alcohol abuse and the share of teenage drivers. He finds that the county population density, the presence of interstate highways in rural counties, the prevalence of severe alcohol abuse, the proportion of teen drivers and the presence of a large college student population all have statistically significant relationships with county fatality rates; while for most counties the correlation between per capita income and road-related deaths is not statistically significant. La Torre *et al.* (2007) identify in addition the employment rate and alcohol consumption as important determinants of road traffic fatalities (both are positively associated with fatalities). However, both studies suffer from a possible omitted variable bias since they do not control for regional or county-fixed effects.

Only very few studies analyze the determinants of road traffic fatalities at the individual level, such as for instance the relation between individual income and driving behavior and how different types of individuals respond to different laws and forms of enforcement. The understanding of why individuals engage in risky behavior such as drink and drive, excess speed, infringement of traffic rules etc. might be particulary important to design and target effective policies.

Fosgerau (2005) uses a large cross-sectional dataset from the Danish National Travel Survey (1996-2001) and shows that speed decreases with age, men drive faster than women, singles drive slightly faster than married individuals and speed decreases with urbanization. He also shows that the effect of income on speed is positive and highly statistically significant. He argues that a higher income increases the perceived value of time and decreases the 'real cost' of fines and other speed dependent user costs (noise for instance), which are independent of own income; thus, so the hypothesis, higher income leads to higher speed.

Factor *et al.* (2008) emphasize the importance of social and cultural characteristics. They use a data set which merges Israeli census data with road traffic accident records. Estimating a logistic regression where the dependant (latent) variable is the probability of drivers from different social groups to be involved in a fatal or a severe road accident, they show that Muslims, separated and widowed people, males, young people, low-skilled workers and less educated individuals have a higher chance to be involved. The authors conclude that traffic accidents may in part be socially generated. They refer to the different habits, skills and styles of each sub-group, which may imply different risk-taking levels.

2.3 Explaining road user's behavior

Only a few authors have made an attempt to explicitly model the behavior of drivers. Exceptions are for instance Blomquist (1986), Boyer and Dionne (1987) and Bishai *et al.* (2006)). In the models suggested in that literature drivers typically are confronted with accidents of a certain probability of occurrence, that depends on own safety efforts (use of safety belt, speed, vehicle quality) and other drivers' driving behavior as well as exogenous safety measures. The 'music' in these models comes from the assumption that on the one hand own safety efforts and exogenous safety measures create a disutility because they involve time costs, discomfort, energy and money, on the other hand, in case of an accident the driver has to bear the costs of the accident such as car repair and medical services. Drivers are assumed to weigh these costs against the benefits in order to maximize their expected utility. It is easy to show that in such a setting, one may find that drivers decrease own safety efforts in response to an increase in exogenous safety measures. For instance the introduction of safety belts may lead to higher speed. Keeler (1994) found some evidence for this kind of behavior using panel data for the US. Similar findings exist in the area of HIV/AIDS prevention policies. A study based on a randomized controlled trail found for instance that a higher prevalence of condom use following an information campaign was accompanied by more risky sexual behavior (Kajubi, Kamya, Kamya *et al.*, 2005).

This finding leads to another interesting question. Does the effectiveness of campaigns which inform about the consequences of risky behavior depend on risk-aversion or even change the risk attitude? Kenkel (1991) shows, for instance, that smoking behavior is responsive to health knowledge. Nevertheless, the author also stresses that formal education still has an impact on health behavior even if health knowledge is controlled for. The expected interactive effects of schooling and health knowledge on alcohol consumption or exercise are not found. According to the author, the differences in the respective stigma attached to these activities across socioeconomic groups may explain this result. Yet, Cook and Bellis (2001) find based on (a rather unrepresentative) survey among students that behavior and knowledge about the risks are uncorrelated. But they also find that the perception of risk is related to risk aversion. They identify being male, being younger, having parents in white-collar occupations, belief in God and early exposure to risk as factors that reduce risk aversion. The authors conclude that an effective provision of health information does not only need to transmit the knowledge but requires also an intimate understanding of the media, culture and public perception.

2.4 Assessments of road safety measures

The understanding of individual behavior is crucial to understand and assess the effectiveness of other interventions as well, not just information campaigns. Lave (1985), for example, examines traffic fatalities in conjunction with speed limit legislations across US states and concludes that speed limits are not an adequate policy. He argues that not the average speed but the variance of speed (absence of coordination) causes traffic fatalities.[11] A problem of that argument is of course that the variance of speed is rising in the average speed, so the results do not rule out the fact that a lower speed leads to less fatalities holding constant the variation in speed. It is hard to believe that both the occurrence and the severity of car crashes are independent of the level of speed at which crashes happen and just depend on the difference in speed. This and other studies do also not properly control for the degree of the enforcement of speed limits.

Yamamura (2008) is among the few having investigated this issue. Using panel data from 46 Japanese prefectures for the years 1988 to 2000, Yamamura empirically examines the role of social norms (reinforced by social capital and social structures) for driver's attitudes, in particular dangerous driving. Social capital and social structures are proxied by the number of community centers in the prefecture, the share of emigrants to other prefectures, and the share of

[11] A standpoint which is also taken by the German car industry to lobby against a general speed limit on German motorways.

immigrants from other prefectures. The study controls for a number of variables, including the number of policemen, which are seen as a proxy for 'formal' deterrents. Given that this variable is likely to be endogenous, it is instrumented using income. The involved exclusion restriction can of course be doubted since income itself has to be seen, as shown above, as a determinant of driving behavior. However, taken together the study finds that formal deterrents hardly affect dangerous driving behavior, whereas informal deterrence prevents drivers from driving dangerously (but does not necessarily enhance attentive driving). Similar to the studies cited above, this study also finds that mandated safety inspections induce drivers to drive less attentively (the 'off setting effect').

Carpenter (2004) uses the US American Behavioral Risk Factor Surveillance System (BRFSS), which is a large state representative telephone survey collecting information on alcohol consumption and drunk-driving behavior for young adults 18 years and older to assess the effects of the "Zero Tolerance" policies. The empirical model accounts for unobserved state, year and seasonal fixed effects. The author also introduces in his regression other control variables such as drink-driving laws, the state unemployment rate, the state beer tax and the state minimum legal drinking age. The author finds strong evidence that the main effect of the "Zero Tolerance" policy was to reduce heavy episodic drinking by males aged 18 to 20. An increase of the beer tax or changes in the minimum drinking age are shown to be less effective as they tax all levels of drinking instead of those that lead directly to the alcohol-related traffic fatalities.

Bertrand, Djankov, Hanna *et al.* (2006) emphasize the role of corruption in getting a driving licence. Using an experimental design, they analyzed the administrative process to get a licence in Delhi, India. Participants were randomly assigned in one of the three following groups: participants in group 1 received an important financial bonus if they manage to get their license within 31 days (the statutory minimum delay being 30 days); participants in group 2 were offered free driving lessons; and participants in group 3 served as a comparison group, i.e. they were exposed to the standard procedure. The authors find that bureaucracy is responsive to individual needs (the individuals from the bonus group are 20% more likely to obtain the driving license and get it more rapidly (in a 40% shorter period of time), but is unresponsive to driving skills; the participants from the lesson group are only slightly more likely to obtain a license than the comparison group and far less likely than the bonus group. Thus corruption annihilates the purpose of the driving license regulation, as unsafe drivers can easily 'find their way to the roads'.

In another experiment, Habyarimana and Jack (2009) randomly selected Kenyan group taxis into treatment and control groups. Minibuses in the treatment group were equipped with stickers encouraging passengers to complain and alert the driver if they feel unsafe because of the driver's hazardous behavior. The authors find a significant reduction of 45% in insurance claims in the treatment group, and a three times higher heckling rate reported by drivers and passengers in minibuses with stickers.

2.5 Studies on road traffic crash victims

Another, again small, strand of the literature investigates the determinants of the involvement of road users and the health and economic burden victims have to carry. As one can expect, the typical profile of victims varies a lot between low and high income countries. Whereas in low income countries pedestrians and (motor) cyclists are the most vulnerable road users, car occupants dominate in high income countries (see e.g. Jacobs *et al.*, 2000; Ansari *et al.*, 2000; Montazeri, 2003; Regional Health Forum of South-East Asia, 2004; Paulozzi *et al.* (2007) and WHO, 2009). Again, not much is known about within country variation, i.e. whether poorer population groups are systematically more affected than richer groups. But a study in Bangalore, India seems to provide some evidence for such a negative gradient in income (Aeron-Thomas *et al.*, 2004). This correlation is mainly driven by the fact that different income groups use different transport means. The study by Factor *et al.* (2008), cited above, also suggested for the case of Israel that among the most vulnerable road users are minorities, low-skilled workers and individuals with low education.

Given the limited space of this note, we have certainly not given justice to all the work which has been done on the economic aspects of road traffic crashes, but nevertheless to us it seems to be, in particular compared to other health problems, an under-researched area. This is in particular true concerning the determinants of driving behavior. A good starting point to make further progress in this field would be to elaborate a rigorous conceptual framework of driving behavior and to test such a model using an experimental design. The theoretical side would certainly benefit if it addressed the interaction between risk attitude and time preference (see e.g. Van der Pol and Ruggeri, 2008).

3 Data availability

Reliable and systematic data on road traffic injuries and fatalities is scarce. Although we counted five different international road traffic data bases, the analysis of cross country patterns is hampered by a lack of harmonization and coherence of the data and a general lack of reliable statistics in most low income countries which usually have no systematic vital registration system and where a large number of road crashes and casualties are not declared to the police (see also Jacobs *et al.*, 2000). In some countries, less than half of the deaths that happen as a result of road crashes are reported to the police. Jacobs *et al.* (2000) estimate that under reporting rates range from 0-25% in high motorized countries up to 350% in some less motorized countries.

The five road traffic databases are the International Road Traffic and Accident Database (IRTAD), the International Road Federation World Road Statistics (IRF), the United Nations Economic Commission for Europe Database (UNECE), the World Health Organization Database (WHO) and the Community Road Accident Database (CARE).[12] Table 1 below describes the variables included in these different databases, the period and the countries covered.

Three out of these five databases have only data for a sample of highly motorized countries. Motorization is indeed a more recent phenomenon in developing countries but less efforts have also been made in low and middle income countries to implement a traffic accident surveillance system. Moreover, the available international databases of fatal road crashes include exclusively aggregated data, except the CARE database which also includes disaggregated information. The starting year of the data collection varies substantially between countries which limits the possibilities of examining long term trends. In principle disaggregated data is contained in most national databases (e.g. disaggregated by region of residence, age and gender), however, the large majority of countries deny access to this data. All these caveats make it quite difficult to undertake rigorous research on the determinants and consequences of road traffic fatalities.

The lack of harmonization of terminology between different data bases but also between and even within countries in the same data base (i.e. due to differences between health sector and police records) further limits the comparability of data. For instance, to define road traffic fatalities, different criteria are applied regarding the time that can elapse between a crash and the death event. In some countries only immediate death events are counted. In other countries a death event is still considered as a road traffic fatality if the death occurred a year after the accident actually happened. The agreed standard is in principle 30 days after the accident, but not all countries comply with this standard, partly because some rely on police and others on hospital records. To solve this problem the WHO uses for instance the ECMT standardized 30-day-road-crash-fatality-adjustment-factors in order to adjust all countries' road traffic fatalities to the same definition (WHO, 2009).[13] Inconsistent terminology becomes even a bigger problem when focusing on severe non-fatal injuries.

With harmonized and more regularly collected data, assessments of the determinants and consequences of road traffic crashes could be greatly improved. Moreover, an evidence-based design of prevention campaigns and interventions to take care of victims also require disaggregated data on perpetrators and victims by age, sex, education, socio-economic status etc. Such a data base could be complemented by other road-related performance indicators, such as the number

[12] See also Luoma and Sivak (2007).

[13] The 'European Conference of Ministers of Transport' (ECMT) recommends adjustment factors to adjust all reported country data to the 30-day standard. For example, if the country reports only the road deaths occurring immediately after the accident, an adjustment factor of 1.30 should be applied.

of pedestrians crossings, number of safety audits conducted, number of hazardous locations reduced and the degree of enforcement of traffic related laws. Finally, country-specific data on health resources used to deal with traffic fatalities and injuries would be a useful addition.

Even more difficult is the analysis of the determinants and consequences of road traffic accidents at the individual level. In almost all standard household surveys conducted in low and middle income countries, such as the World Bank's *Living Standard Measurement Survey* or Macro International's *Demographic and Health Survey*, there is to our knowledge and with a very few exceptions, no specific question on road traffic accident related injuries and fatalities. As there are vehicle-related questions and questions on health expenditure, adding some specific questions about road traffic participation and accidents could be of great help to explore the profile of road users involved in road traffic crashes and thus allow to target them more accurately. These kind of questions would also help estimate the impact of such accidents on households' living standards.

4 A cross country analysis of road traffic crashes and driving behavior

4.1 Specification and variables used

In this section we use a larger cross section and a smaller panel of countries to analyze the determinants of road traffic fatalities. Obviously, this analysis is limited by several factors. First, as outlined in the previous section, the quality of road traffic statistics varies a lot from country to country. For many very poor countries the statistics are entirely based on (rough) estimations. Hence, to test the robustness of our results we will use different samples of countries. Second, as outlined above, definitions of road traffic fatalities are not homogenous across countries. Third, information on many explanatory variables, that are potentially important, such as the quality of registered motorized vehicles, the quality of roads or the actual average speed are not available. Thus many important effects will necessarily remain with the residual.

More precisely, using the cross-section of countries we estimate the following model:

$$\ln(fatalities_i) = \beta_0 + X_i'\beta_1 + \beta_2 \ln GNI_i + \beta_3(\ln GNI_i)^2 + Region_i'\beta_4 + \epsilon_i, \quad (1)$$

where $\ln(fatalities_i)$ stands for the log number of road traffic fatalities per 100,000 population.[14] This data is taken from the WHO and refers to the year

[14] Note that we did neither make an adjustment for potential underreporting, nor did we correct for differences in road traffic fatalities due to different periods after which an injured victim who died is still declared as a road traffic fatality.

2002.[15] Obviously, the number of road traffic fatalities is a count, hence a count data model is in principle more appropriate than a ordinary least square (OLS) specification. However, for the sake of a simple interpretation, we present and discuss the OLS results but check their robustness by comparing them with the estimates obtained using a negative binomial regression model.

The vector X_i stands for a vector of potential determinants, also observed in the year 2002, such as road infrastructure, urbanization, population density, institutional quality, driving related behavior, quality of public health supply, education and life expectancy. All these variables are discussed in detail below.

To test whether the 'degree of motorization' of a country has any effect on the frequency of traffic fatalities per capita, we include the number of vehicles per capita (in 2002) and the number of vehicles per road km (in 2002) in X_i. Both variables are taken from the World Development Indicator data base 2008 ('WDI data base', hereafter). We expect that the number of vehicles is positively related to the frequency of road traffic crashes and thus fatalities. However, the relationship might be non-linear. A high number of crashes may lead to the adoption of safety measures such as improved car safety, better road management and other interventions that in particular protect vulnerable road users.

To measure the quality of road infrastructure, we use the length of paved roads as a share of the total road network (provided by the CIA-fact book). We expect that a higher share of paved roads reduces the number of fatalities. However, this variable is a rather imperfect measure of road quality, since a badly maintained paved road, i.e. with frequent pot-holes, may present a higher risk than unpaved roads on which traffic is relatively slow. To reduce the number of missing values, we used for each country the information for the year which is the closest to 2002. This means for some countries to rely on observations from years as far as 2000 or 2006. Yet, we assume that with a few exceptions road networks are not substantially expanded within such a short period of time.

We also include population density as a potentially relevant regressor. In which direction this variable will play is difficult to say in advance. On the one hand, a higher population density means more people using the same roads which should increase the probability of road traffic crashes. On the other hand, due to congestion and traffic jams which are also increasing in population density, the probability of having a fatal accident may be reduced (see e.g. Keeler, 1994). Even if the number of accidents may be higher, they may be less severe given a lower average speed. We also include the urbanization rate in the regression. Likewise, we assume that a higher urbanization rate, means more traffic and a higher density of vehicles and vulnerable road users. Both variables are again taken from the WDI data base.

We also test for a set of variables of which we think they may capture behavior

[15] Data files produced by the Department of Measurement and Health Information (published December 2004).

of road users. First, we include the adult literacy rate, as road traffic accidents may be partly caused by the ignorance of traffic rules and regulations. For instance, traffic signs must be understood and the rules known in order to have well coordinated traffic flows. The adult literacy rates are taken from UNDP's *Human Development Report*.[16] Moreover, we include the population age structure as a regressor, because a number of studies suggest that young, in particular male, road users tend to drive in a riskier way and are over-proportionally involved in road traffic crashes (see e.g Cook and Bellis, 2001; Factor *et al.*, 2008). Hence, we expect that countries with a higher share of potential young drivers experience more fatalities. Information about the countries' age structure is again taken from the WDI data base.

Hersh and Viscusi (1990) found that preferences related to health related activities, such as tobacco consumption and seatbelt use, are relevant determinants of the 'wage-risk tradeoff'. Therefore, the prevalence of such activities we may also contain some information, which is relevant for the individual risk-taking behavior on the road. Therefore, we include smoking prevalence in our regression. This variable can be taken from the *Tobacco Atlas* published by the WHO. Given that smoking can induce major health problems and cause premature mortality (and given that this is well-known by most smokers) we hope to capture with this variable risk-aversion towards health problems and mortality. Yet, it is likely that smoking behavior is also driven by cultural factors, that are probably independent of risk-aversion. We also include life expectancy in our set of regressors, since, one may argue that people who are likely to die prematurely will be more prone to engage in behavior that yield short term benefits at longer term costs.[17] Life-expectancy is also taken from the WDI data base.

Road crash statistics also suggest that many accidents are caused by, or at least involve, alcohol abuse. Hence, countries with a higher alcohol consumption may also have more road traffic fatalities. Similar to Traynor (2008), we use the number of deaths due to cirrhosis of the liver, alcohol use disorder, suicide and homicide in 2002. In contrast to Traynor, we explicitly exclude deaths due to alcohol-related traffic crashes as this would be endogenous in our regression.[18] This variable is taken from the WHO mortality data base and refers to the year 2002.

[16]Note that we recoded missing values for high income countries to 100%, thus neglecting that in some of these countries a small share of the population is not able to read and write.

[17]A WHO report states for instance that the expectation of premature mortality of those living near Chernobyl led to a widespread perception of people to feel 'helpless', 'weak' and 'in lack of control over their future'. These perceptions then translated in a higher consumption of mushrooms, berries and game from areas still designated as highly contaminated, overuse of alcohol and tobacco, and unprotected promiscuous sexual activity (see WHO, 2005 and also Lorentzen et al. (2008)).

[18]Traynor (2008) includes death events due to cirrhosis of the liver, alcohol dependence syndrome, non-dependent abuse of alcohol, alcoholic psychosis, alcohol poisoning, suicide and homicide, and motor vehicles crashes.

Jacobs and Cutting (1986), Van Beeck *et al.* (2000) and Bishai *et al.* (2006) have, among others, emphasized that the quality of trauma and medical care are crucial determinants of the survival chances of road crash victims. Although we think this effect is difficult to capture, we test three alternative measures of health supply: the number of available hospital beds, the number of physicians and the number of nurses per country and 1,000 inhabitants. All three variables are again taken from the WDI data base. We proceed in the same way as for the other variables: for countries for which the information is not available for the year 2002, we take the available information for years close by.

To control for the existence and the enforcement of traffic rules and regulations, we also test whether some of the variance in road traffic fatalities across countries can be explained by differences in the quality of institutions. To do so we include Kaufman's *et al.* (2003) institutions indices for 2002. These variables may also allow to capture the prevalence of corruption and the respect of rules and regulations. In countries where corruption is widespread, the incentive to respect rules and regulations may be very low, since major legal steps may be avoided by bribing police officers and public bureaucrats.[19]

Besides all the structural characteristics listed above, we also include the log of Gross National Income (GNI) in international \$ PPP in our regression. This data is also taken from the WDI data base. It should account for a possible direct effect of aggregate income on traffic fatalities and for indirect effects, that are not captured by the variables included in X_i, such as traffic system management, the quality of vehicles and the use of helmets. Because the role of income may vary a lot across poor and rich countries, we test in each case for a linear and non-linear effect of $\ln GNI_i$. Table 2 lists the data sources of all variables used in our analysis.

We also test for regional specific effects ($Region_i$) to see whether there are significant effects specific to different regions in the world. Such differences could have historical and cultural roots or reflect different levels of development not fully captured by the income dimension. Nevertheless, we are fully aware of the limits of cross-country regressions of the type we are running here and we will be very careful in interpreting our results. Obviously, in this kind of setting, measurement error, parameter heterogeneity and omitted variable bias pose major estimation problems.

Given the differences in the availability and quality of data, we define four different country samples. First a sample (sample a) of all countries for which our dependant variable and GNI are available.[20] This sample covers most of the

[19]See e.g. Bertrand *et al.* (2006) on corruption in the process of getting a driving license and its implications for driver's driving ability.

[20]We actually exclude four countries (Angola, Iran, Sierra Leone and the United Arab Emirates) which have a particularly high rate of estimated road traffic crash fatalities and we suspect that this is partly due to measurement error. More precisely, we excluded all countries in the 99th percentile of the distribution of road traffic crash fatalities, i.e. countries with more

countries in the world (166 countries). Second, a sample of countries (sample b) for which all potential independent variables are available and which have a population size larger than one million[21] (112 countries). Third, a sample of countries (sample c), in which we keep from the former sample only those countries which have good quality road traffic fatality statistics (70 countries).[22] Fourth, a sample of OECD countries only (sample d, 28 countries). It is important to note that while sample b includes low, middle and high income countries, the better quality sample (sample c) does almost only include middle and high income countries. Table 3 provides the list of countries included in each sample, Table 4 shows the descriptive statistics of all variables used and Table 5 provides the linear correlation coefficients between these variables (for sample b, if nothing else is specified).

The cross-sectional estimates bear of course the risk of a non-negligible bias due to unobserved heterogeneity. Potential candidates for such variables are cultural attitudes, enforcement levels of rules and regulations and conditions of roads and vehicles. For this reason we also consider panel estimates, that can control at least for all those unobserved factors that are constant over time. The cost is of course a smaller sample of countries given that for many countries time-series data is not available and the impossibility to look at the effects associated with observed time-constant variables. Hence, the focus will be on the effects related to income and those related to the few time-varying explanatory variables we can introduce. The model to be estimated reads:

$$\ln(fatalities_{it}) = \beta_0 + X'_{it}\beta_1 + \beta_2 \ln GNI_{it} + \beta_3(\ln GNI_{it})^2 + \mu_i + \epsilon_{it}, \qquad (2)$$

where t is the index for time and μ_i is the country fixed-effect (or alternatively random-effect). The countries that are included in the panel data set are indicated by a $*$ in Table 3, column (1). There are only four countries from Sub-Saharan Africa and ten from the Asia and Pacific region. The data set covers the period 1980 to 2007. The panel is unbalanced. In total we have 1,411 country-year observations; between 55 and 70 for each year, except in most recent years where we have significantly less. Again, we exclude outliers and test the sensitivity of the results with respect to the inclusion/exclusion of certain countries.

than 50 deaths per 100,000 population.

[21]Following Söderland and Zwi (1995) and Van Beeck *et al.* (2000), we exclude countries with a population of less than one million because of potentially important variations in the year-to-year reported mortality figures. A multi-year average would in principle be needed to get a representative number.

[22]The used road traffic accident fatalities come from data sources of different quality: Complete death registration data (level 1), incomplete death registration data (level 2), information on causes of death based on verbal autopsy methods (level 3), and no information on causes of death available for most causes (level 4). We include in our better quality data sample only the countries which provide level 1 or level 2 quality information.

4.2 Results

The descriptive statistics in Table 4 reveal major structural differences across the four samples we consider. For many variables these differences can be directly related to the large differences in income between these samples for others this is less obvious. Our dependant variable, the estimated number of road traffic crash fatalities is about 19 per 100,000 population in sample b, 14 in sample c (the better quality sample) and 11 in sample d (OECD sample). However, it is interesting to see that the rate of alcohol related causes of death (cirrhosis of the liver, alcohol use disorder, suicide or homicide) is higher in the better quality and richer sample than in the all country and thus poorer sample. Different factors may explain this pattern. First, alcohol in many poorer countries is just too expensive for a large part of the population. Second, religious beliefs often limit alcohol consumption, in particular in muslim countries. Third, in poorer countries people often die prematurely due to other causes, and thus 'do not have the time' to die through alcohol-related causes.

Given that we suspect many variables in our data set to be transmission channels between road traffic crash fatalities and income, we provide in Table 5 the pairwise correlation coefficients between all variables and in particular between GNI per capita and all other variables. GNI per capita is strongly correlated with population structure, urbanization, life expectancy, the number of vehicles per 100,000 population and with Kaufman's *et al.* (2003) institution indices. The correlation coefficient between GNI per capita and the estimated road traffic fatalities per 100,000 population is -0.47. The main challenge in our regression analysis is to disentangle the effect of income per se and the contribution of channel variables such as population density, traffic density, risk taking behavior, alcohol consumption etc.

Table 6 shows the results from the multiple regressions. For each sample we first present a regression using the log of income (and, depending on the sample, the log of income squared) alone. Income is significant in all samples, except the OECD sample, but the form of the relationship between income and fatalities varies across the samples a, b and c. The income effects are visualized in Figure 1 (first row). The fitted curves are non-parametric locally weighted regression lines. We see a clear negative relationship in sample a and sample b. We find that an increase in sample a's median income by \$5,000 almost halves the number of road fatalities per 100,000 population, while in sample b this same absolute change in the median income leads to decline of about 16%. The above discussed inverted-U shaped relationship, which was found by others before, appears when we limit our sample to those countries which have better quality data, and, hence, to countries which are on average also richer. In OECD countries there seems to be no strong association between income and fatalities. This seems plausible as here factors such as enforcement of rules and regulations, driving behavior and traffic density should explain most of the variance, whereas income per se should only play a minor role. This result is, as will be seen below, confirmed by the panel data analysis.

We now introduce in each sample additional explanatory variables to see whether we can further reduce the part of the unexplained variance and whether some of these variables can be considered as transmission channels between income and fatalities. We show all effects which were significant at the 10% level in a regression where income was the only other regressor. However, we were not able to include further regressors in the sample of OECD countries. This is on the one hand due to the small sample size and on the other hand, we suspect, due to the fact, that in these countries those variables which might be relevant are unobserved (e.g. drink-driving regulations and their enforcement, trauma care, the safety of vehicles and also patterns of driving behavior).

Concerning the all countries sample b (column 3), we note that the main determinants of road traffic deaths per 100,000 population are the number of nurses per 1,000 persons, the urbanization rate, the voice and accountability governance index, the number of alcohol related deaths per 100,000 population, the male life expectancy and the adult literacy rate. As expected, the medical supply and better governance are negatively correlated with the dependent variable while the urbanization and the behavior-related variables are positively correlated to road traffic crash fatalities. Despite the fact that violence was statistically significant, we decided not to include this variable in the multiple regression as it is highly correlated with the variable measuring death events caused by alcohol.[23]

The quality and intensity of trauma care in a country may have important effects on the survival of road crash victims. Our results are consistent with this hypothesis since we find that an increase of 1% in the number of nurses per 1,000 inhabitants induces a decrease of 0.23% of road related deaths per 100,000 population. Given that on average there are approximately 4 nurses per 1,000 inhabitants (in sample b), one more nurse per 1,000 population would lead to a 6% decline of road traffic fatalities, i.e. would save the live of one additional victim per 100,000 population per year. However, of course we cannot rule out an omitted variable bias here. The number of nurses may capture other effects related to the health system or development more generally. Moreover, the number of nurses says of course nothing about their distribution within a country, they may be highly concentrated in urban and richer areas. Our variable does also ignore the quality of the care provided by nurses.

We find that an 1% increase of alcohol related death events is associated with an increase of 0.25% of road traffic crash related deaths. Provided that the number of alcohol-related death events per 100,000 population is an acceptable proxy of the share of inhabitants that experience serious alcohol problems, this effect may capture the problem of drink-driving.

[23]The significance level of alcohol related death events declines from 5% to 10% when violence is included

Concerning population density, we note that while this variable had a negative sign and was statistically significant in a regression just with income as a co-regressor it is no longer significant in the multiple regression, although the variable still has a negative sign suggesting that a higher population density is associated with less fatalities, but it is difficult to disentangle the effects of the various variables, given that the involved multicollinearity, as the correlation matrix showed, is relatively high.

When we examine the better quality sample results, we find that population structure, the number of nurses and alcohol related deaths per 100,000 population are the only statistically significant determinants of road traffic crash fatalities. The insignificance of the urbanization rate can be explained by the higher level of urbanization in sample c and less variation of this variable in this sample.

In columns 4 and 7 we introduce regional dummies in order to capture cultural or regional characteristics that the other variables are not reflecting. We see in column 4, that once we introduce the regional dummies, the voice and accountability indicator, adult literacy and male life expectancy are no longer statistically significant. These variables do indeed show strong regional patterns. Yet, Africa seems to be the only region which is significantly different from the other regions, once the other variables are controlled for. We also observe that the effect of alcohol related deaths per 100,000 population is now even more pronounced. In the better quality data sample, we find that once the regional variables are included in the regression, the main determinant of road traffic fatalities is alcohol related deaths per 100,000 population. We stated above that we find in the better quality data sample the highest average number of people dying from alcohol related causes. In this sample, a 1% increase of alcohol related deaths is associated with a 0.44% increase in road traffic crash fatalities, which is higher than in the all country sample (sample b).

Our regressions for sample b and c explain a quite important part of the total variance in the data. The R^2's are 0.604 and 0.458 in the column 4 and column 7 regressions respectively. If income is included as a regressor alone we explain about 10% to 27% of the total variance.

In Figure 1 (second row) we now show the partial correlations between income and fatalities. These curves show the correlation between income and fatalities, once all other effects are controlled.[24] The fitted line corresponds again to a (non-parametric) locally weighted regression line. We can see that in virtually all samples the association between income and fatalities disappears. One can just state a weak inverted U-shaped pattern among the upper end of the middle and high income countries. Hence, the transmission variables we considered explain a very large part of the total effect associated with income in a single regression.

However, as mentioned above, the cross-sectional estimates may be biased

[24]Fatalities net the impact of all other explanatory variables is obtained by subtracting the predicted fatalities from a regression with all regressors, except income, from observed fatalities.

due to unobserved heterogeneity across countries. Therefore we consider now the panel estimates. Table 7 shows 3 sets of estimates; for all countries, for the high-income countries and for the low and middle-income countries. For the sample of all countries (Table 7a) we start with a regression of fatalities on income controlling for country-fixed effects. Then we introduce subsequently time-effects, time-regional interactions and a small set of additional time-varying covariates; the share of the population aged between 15 and 64, the share of the population above the age of 64, the log of population density and life expectancy at birth. Hausman tests showed (not reported) that estimates with fixed-effects are slightly different from estimates with random-effects, hence we use fixed-effects.

Col. (1) of Table 7 shows that the relationship between income and road traffic accident fatalities follows a clear inverted u-shaped pattern, with a turning point at about $ PPP 8,000 GNI per capita. This is also illustrated in Figure 2, which shows the scatter plot of GNI and fatalities. Adding time-effects (col. 2) and time-regional interactions (col. 3) reduces the effect associated with income, but the u-shaped pattern persists. The share of the explained within-variance rises to 39 percent. In column (4), we add the additional covariates. This reduces the sample by about 300 country-year observations due to missing values.[25] However, we still find the inverse u-shaped relationship between fatalities and income. We explain about 24 percent of the within-country variance. The fatality rate decreases in both the share of the population aged between 15 and 64 and the population above 65. Fatalities increase with population density. Again, we did not have clear prior on this variable. On the one hand a higher density may of course increase the probability of an accident. On the other hand, a higher density may reduce the average speed and thus make accidents less likely. Here, the first effect seems to dominate. Finally, fatalities decline with life-expectancy. Given that we control for income in these estimates, the effect linked to life-expectancy may suggest that a low life expectancy, indeed increases the time-discount rate and leads road users to engage in more riskier behavior. We cited in our literature review a few studies that found empirical evidence for this kind of effect. Moreover, Lorentzen *et al.* (2008), showed that this channel may even explain the African dummy in regressions of economic growth; countries with high mortality would show lower investment in human and physical capital and higher fertility. Ideally, one would like to use here a life-expectancy estimate where the effect of road accident fatalities is netted out, however we assume that life-expectancy it-self is not substantially affected by fatalities, thus we do not suspect a strong endogeneity bias here. If we add time-effects and time-region interactions, the income effects become insignificant. Showing that within regions income evolves similarly, which is not surprising. The effects associated with population structure change their sign, but only the share of the population aged between 15 and 64 is significant, and only weakly. The effect of life-expectancy is

[25]The results of columns (1) to (3) are robust to the use of this smaller sample.

still negative, but also only weakly significant. The share of the explained within variance rises to 43.3 percent.

If we limit the sample to the high-income countries the u-shaped pattern also disappears if we control for the other variables (col. (4)). The effect associated with population density is also insignificant. However, the effect related to life-expectancy is still negative and significant and larger in magnitude than in the previous sample. The share of the adult population is, as one would expect for high-income countries, positive. This regression explains about 60 percent of the total-within variance.

If we look at the low and middle income countries alone, the income effect also disappears if we control for the other variables (col. (6)). The effects associated with the population composition show that 'older populations' have less fatalities. However, neither population density nor life-expectancy at birth are significant.

Hence, the panel estimates confirm a weak u-shaped relationship between road traffic accident fatalities and income as we go from low income to high income countries. Within low and high-income countries, income does not explain much of the variation in road traffic accident fatalities.

4.3 Limitation of the study and conclusions

The strength of our analysis is that we consider a range of environmental, economic and social factors not considered by most of the previous studies and that we include also a large set of low and middle income countries in our analysis. This allows us to explore in detail the potential transmission channels between income, development and road traffic accident fatalities and to point at least to some extent to those areas, where interventions might be particularly effective.

However, considering the relationship between road traffic safety and development in such detail also comes at a cost. Many of the variables other than income we consider are not available on a periodical basis, in particular for the poorest countries in our sample. Moreover, the inclusion of many low and middle income countries, means to rely for many countries on estimated fatality rates rather than observed ones. This again may bias our estimates.

Finally, of course our analysis also suffers from the omission of many variables which could in principle be observed, but probably at a high cost, such as past and ongoing road safety policies, drink-driving laws, the knowledge of rules and regulations by road users, the quality of vehicles and the quality of roads. The inclusion of these variables will be left for future work.

5 The gaps to be filled

The WHO promotes in its efforts to reduce the number of road traffic crash injuries and fatalities the so-called "*System approach to road safety*". This approach organizes priorities according to two levels. First, governments should enforce road rules, understand the causes of crashes and risks, to educate and inform road users and to regulate the admission to 'the system' by licensing vehicles and people. Second, governments should enforce safe vehicles and speeds and provide safe roads and while warning road users to prevent crashes. Although, we think this approach points to a number of important action fields, it is a too narrow perspective of the problem, at least with respect to the poor and very poor countries. We think that many of the prevailing problems cannot be seen independent of the problem of poverty and, therefore, without taking into account poverty many of the reforms and interventions will be ineffective. In the following we explain why we think this is the case and then indicate which type of research, we think, is needed to design interventions which are more effective in a poor-country context.

First, the enforcement of road rules can only be implemented up to a point at which road users can bear the costs to comply with these rules. Vehicle safety maintenance, safety equipment such as helmets, safety belts and child restraints as well as driving lessons and licence are 'goods' which for most road users in poor countries are too expensive. Enforcing rules that require these goods would mean to exclude poor road users systematically from the system, which would be unacceptable not only from a social but also from an economic point of view, since it would deprive the poor from many potential income generating activities and thus further reinforce the problem of poverty. Moreover, enforcement of rules may also be hindered by low paid police officers which are either unmotivated and inactive or highly corrupt.

Second, safer roads and sideways require heavy investments which in poor countries with serious budget constraints compete with many other necessary expenditures in basic services in the area of education, health and food security. Hence, advising poor countries to invest in road safety must take into account financial realities in these countries. Again, we think, the problems cannot be seen independently from the problem of poverty.

Third, the risk taking behavior of road users particularly in low and middle income countries may by a large extent also be determined by income. Many road users may constantly face a trade off between complying with the rules or gaining time and income by infringing the laws. Taxi and mini bus drivers, for instance, excess also speeds and overload vehicles to be able to pay the rents on their capital and to earn at least a subsistence wage, or, if employed, to secure their job. However, we do not deny that there are also many other factors determining behavior and explaining why some take more risk than others, for instance by drinking and driving. These factors have to be understood. Culture and religious beliefs (through ideas such as fatalism and destiny), but also family background characteristics may play a role. Behavior and attitudes are certainly also shaped by awareness of risks and the ability to deal with information about risks.

To address these three problem areas, we think research in the following directions would be useful. First, regarding the enforcement of safety measures, it would be good to collect representative data among road users and to find out why safety measures such as helmets, safety belts or child restraints are not used. A lack of risk awareness and the costs for these measures (including supply constraints) may figure prominently among the answers. To design effective interventions addressing these problems, it would be useful to conduct randomized controlled trials where treatment and control groups receive different information of potential risks, get safety measures and driving lessons for alternative subsidized and unsubsidized prices and are confronted to alternative enforcement levels. In such a setting one could explicitly explore the role of poverty. If correctly implemented, such experiments may allow to get a good sense of the appropriate policy mix.

Second, to find cost-effective ways to increase the safety level of traffic infrastructure research can contribute with careful cost-benefit analysis, where costs have also to include the cost on the side of victims (medical care, forgone income etc.) and on the level of the national health system.

Third, the collection of micro data on road use behavior attitudes and other socio-economic and cultural characteristics is necessary to understand underlying factors of this behavior and in particular the role of individual income in shaping this behavior. In our literature review we brought up a randomized controlled trial in Kenya where passengers in treatment groups were explicitly asked to complain about the driver's behavior if necessary (Habyarimana *et al.*, 2009). The results suggest that this measure was very effective in reducing the number of accidents. Further interventions of this type are needed to get a sense of what works and what does not. Taxi drivers could be paid a financial reward if they drive without having an accident for a sufficiently long time. Randomized controlled information campaigns and experiments could be used to understand how road users react to awareness campaigns and how different groups deal with information on risk and translate that information in real actions. In contrast to many other health problems, road safety is an area where people, if aware of the risks and of the right attitudes to adopt, can probably have a tremendous impact through simple behavioral change.

We emphasize the possible role played by poverty in causing reduced road safety. Moreover poverty does not only lead to lower road safety, it may also be the case that low road safety increases poverty. Road traffic crash-induced fatalities or injuries can potentially have serious effects on income in affected households and imply excessive out-of-pocket health expenditures. We are not aware of any study that analyzes this two-way relationship in the context of road safety. Hence, this is also an important line of future research. Given the high number of people injured in road traffic crashes and the general difficulties faced by disabled individuals to integrate the labor market, in particular in low and middle income countries, it seems also important to start investigating labor market participation of disabled individuals.

6 Conclusion

In low and middle income countries road traffic accidents have become a major cause of death, in particular for the age group 15 to 44. The WHO anticipates that over the next 15 years, the number of people dying annually in road traffic crashes may rise to 2.4 million. This rise will almost entirely occur in low and middle income countries. Thus in these countries road traffic crash fatalities must be seen as a major health problem, along with AIDS, malaria, tuberculosis and diarrhoea.

Against this background, we reviewed the existing evidence on the (economic) determinants of road traffic crash fatalities. Most of the existing studies take a cross-country perspective and not much is known about relevant factors on the individual level. Yet, such evidence would be needed to think about effective policy interventions. But even on the cross country level, the analysis is hampered by the lack of consistent and exhaustive data over time, in particular in many low and middle income countries. We explored some of the potential determinants using cross-sectional and panel data. We identified a number of important channel variables by which income affects road safety. In particular, we found medical supply, alcohol abuse, the population structure, population density and life-expectancy and the urbanization rate to be significant in a regression of road traffic fatalities on a set of potential determinants including income.

We suspect that in particular in low income countries the lack of road safety is to a large extent rooted in poverty. However, in the same time, we also think that behavior-related factors, independent of income, play an important role. Part of that behavior may be explained by the lack of awareness and a high discount rate on future returns. This is exactly what future research has to find out. We expect, that interventions that have proven to be successful in high income countries are not necessarily effective in low and middle income countries.

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Tables and Figures

Table 1: Countries, period covered and variables contained in the five main road traffic international databases

IRTAD	IRF	UNECE	WHO	CARE
30 developed countries	189 countries	56 countries in Europe and North America	192 countries	14 European countries
Since 1970	Since 1964	Since 1993	Since 1979	Since 1991
Deaths by gender by age group, by road user group, by road types, and by month, area of country, population by age, vehicle by type, road type, area	Number of crashes, injuries and deaths, vehicle in use, distance driven per vehicle type, hour of the day, area of the crash,	Road fatalities, injuries, crashes road conditions, light conditions user type, road type, traffic control, posted speed limit, number of vehicles, location, weather	Number of deaths by age group, age-sex specific deaths rates per 100,000 pop, number of vehicle per km and per 1,000 pop	Person class, gender, age group, vehicle type, area, motorways, day of the week, weather conditions light conditions, use of helmet, collision type

Table 2: Description of the dependent and independent variables used in our analysis

Domain	**Variable**	**Source of information**
Road fatalities	-estimated number of road accident deaths per 100,000 population in 2002	WHO, http://www.who.int/research/en/
Income	-GNI per capita PPP (international current $)	WDI 2008 database
Life expectancy	-male life expectancy	WDI 2008 database
Education	-adult literacy rate	UNDP's Human Development Report 2007-2008
Urbanization	-% of urban population	WDI 2008 database
Population	-population density -population structure	WDI 2008 database
Road infrastructure	-% of road paved -total network in km	CIA fact book https://www.cia.gov/library/publications/the-world-factbook/
Motorization	-vehicle per 1,000 people -vehicle per km of road	WDI 2008 database
Health supply	-number of nurses and midwives per 1,000 people	WDI 2008 database
Behavior	-male smoking prevalence	WHO-Tobacco Atlas http://www.who.int/tobacco/resources/publications/tobacco_atlas/en/index.html
	-estimated number of alcohol related deaths per 100,000 population in 2002	WHO, http://www.who.int/research/en/
Governance	-voice and accountability -control of corruption	WB-Worldwide Governance Indicators, by D. Kaufmann, A. Kraay, and M. Mastruzzi http://info.worldbank.org/governance/wgi/index.asp
Region	-regional dummy	

Table 3: List of countries

Region	**All quality countries** sample a (166)	**All quality countries** sample b (112)	**Better quality data sample** sample c (70)	**OECD countries** sample d (28)
Africa	Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo Dem. Rep., Congo Rep., Cote d'Ivoire, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius*, Mozambique, Namibia, Niger, Nigeria, Rwanda, Seychelles*, Senegal, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia	Benin, Botswana, Burkina Faso, Burundi, Cameroon, Chad, Congo Dem. Rep., Congo Rep., Cote d'Ivoire, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia	Mauritius, South Africa	
Asia and Pacific	Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China*, Fiji, Korea Rep.*, India, Indonesia, Kiribati, Lao, Malaysia, Maldives*, Marshall Islands, Mongolia, Micronesia, Nepal, Pakistan, Papua New Guinea, Philippines*, Samoa, Singapore*, Solomon Islands, Sri Lanka*, Thailand*, Timor-Leste, Tonga, Vanuatu, Vietnam	Bangladesh, Cambodia, China, Indonesia, Korea Rep., Lao, Malaysia, Mongolia, Nepal, Pakistan, Papua New Guinea, Philippines, Sri Lanka, Vietnam	Korea Rep., Malaysia, Mongolia, Philippines, Sri Lanka	Korea Rep.
Middle East and North Africa	Algeria, Bahrain*, Djibouti, Egypt*, Israel*, Jordan, Kuwait*, Lebanon, Morocco, Oman, Saudi Arabia, Syrian Arab Rep.*, Tunisia, Yemen	Algeria, Egypt, Israel, Jordan, Kuwait, Morocco, Oman, Saudi Arabia, Syrian Arab Rep., Tunisia, Yemen	Egypt, Israel, Kuwait, Syrian Arab Rep.	

Table 3 (continued)

Region	**All quality countries** sample a	**All quality countries** sample b	**Better quality data sample** sample c	**OECD countries** sample d
Latin America and Caribbean	Antigua and Barbuda, Argentina*, Belize*, Bolivia, Brazil*, Chile*, Colombia*, Costa Rica*, Dominica*, Dominican Rep.*, Ecuador*, El Salvador*, Grenada*, Guatemala*, Guyana, Haiti, Honduras, Jamaica*, Mexico*, Nicaragua, Panama*, Paraguay*, Peru, St. Kitts and Nevis*, St. Lucia*, St. Vincent and the Grenadines, Suriname*, Trinidad and Tobago*, Uruguay*, Venezuela*	Bolivia, Brazil, Chile, Costa Rica, Dominican Rep., Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela	Brazil, Chile, Colombia, Costa Rica, Dominican Rep., Ecuador, El Salvador, Guatemala, Jamaica, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela	Mexico
Central and East Europe	Albania*, Armenia*, Azerbaijan*, Belarus*, Bosnia and Herzegovina, Bulgaria*, Croatia*, Czech Rep.*, Estonia*, Georgia*, Hungary*, Kazakhstan*, Kyrgyz Rep.*, Latvia*, Lithuania*, Macedonia*, Moldova*, Poland*, Romania*, Russian Federation*, Slovak Republic*, Slovenia*, Tajikistan*, Turkey, Ukraine*, Uzbekistan*	Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Czech Rep., Estonia, Georgia, Hungary, Kazakhstan, Kyrgyz Rep., Latvia, Lithuania, Moldova, Poland, Romania, Russian Federation, Slovenia, Ukraine	Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Rep., Estonia, Georgia, Hungary, Kazakhstan, Kyrgyz Rep., Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russian Federation, Slovenia, Tajikistan, Turkey, Ukraine, Uzbekistan	Czech Rep., Poland, Slovak Rep., Turkey, Hungary
Developed countries	Australia*, Austria*, Belgium*, Canada*, Cyprus*, Denmark*, Finland*, France*, Germany*, Greece*, Iceland*, Ireland*, Italy*, Japan*, Luxembourg*, Malta*, Netherlands*, New Zealand*, Norway*, Portugal*, Spain*, Sweden*, Switzerland*, UK*, USA*	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, USA	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, USA	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK, USA

Notes: Sample a excludes the countries with more than 50 deaths per 100,000 pop.
Samples b, c and d exclude the countries with more than 50 deaths per 100,000 pop and the countries with less than 1 million inhabitants.
The better quality data sample includes countries with complete or incomplete death registration data (levels 1 and 2).
In the first column, the countries followed by a star correspond to the countries that are included in the panel data analysis.

Table 4: Descriptive Statistics

	All countries (166) sample a			All countries (112) sample b			Better quality data countries (70) sample c			OECD countries (28) sample d	
Variables	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD
Estimated number road fatalities per 100,000 pop	17.84	10.29		19.27	9.59		13.79	7.17		11.15	4.69
GNI per capita PPP (international current $)	9050.42	10587.24		8868.75	10296.30		13269.29	11091.28		24145.71	8450.95
% of paved roads				47.07	34.48	(64)	64.35	33.56	(26)	78.91	22.33
Population density (people per square km)				101.97	141.90		112.65	121.89		139.64	133.18
% of urban population				53.13	22.74		65.20	16.17		73.49	10.87
Population under 14 (%)				31.46	11.11		24.27	8.15		18.70	4.08
Population between 15 and 64 (%)				61.00	6.65		65.26	4.06		67.24	1.97
Population over 65 (%)				7.54	5.24		10.46	5.04		14.06	3.46
Male life expectancy				63.72	10.67		70.32	5.66		74.67	2.76
Adult literacy				80.88	21.29	(69)	94.97	7.33		98.83	3.03
Number of hospital beds per 1,000 pop			(93)	3.64	3.09	(69)	4.86	2.95		5.79	2.65
Number of physicians per 1,000 pop				1.53	1.38		2.42	1.09		2.84	0.80
Number of nurses per 1,000 pop				3.91	3.89		6.01	4.05	(26)	8.97	4.00
Number of vehicles per 1,000 pop			(56)	250.52	219.56	(47)	308.55	209.29	(24)	464.71	152.49
Number of vehicles per km of road			(37)	29.65	29.78	(33)	34.15	29.80	(19)	43.74	30.15
Male smoking prevalence (%)			(93)	41.23	14.15	(65)	40.52	12.42	(27)	36.31	11.08
Estimated number of deaths caused by violence per 100,000 pop				9.92	9.69		8.80	12.93		1.87	1.91
Alcohol related deaths per 100,000 pop				36.09	20.75		41.57	24.79	(27)	31.70	16.30
Voice and accountability				-0.05	0.96		0.39	0.90		1.18	0.40
Political stability no violence				-0.11	0.99		0.19	0.96		0.93	0.54
Government effectiveness				0.03	0.99		0.43	1.05		1.48	0.64
Regulatory quality				0.07	0.88		0.44	0.90		1.27	0.46
Rule of law				-0.06	0.96		0.30	1.02		1.27	0.64
Control of corruption				-0.02	1.02		0.35	1.11		1.38	0.87

Notes: We report in the colums “observation” the number of countries for which the variable was available if it differs from the number of countries in the sample.

Table 5: Correlation matrix

	Estimated road fatalities per 100,000 population	GNI per capita	% of paved roads	Population density	Population under 14 (%)	Population between 15-64 (%)	Population over 65 (%)	% of urban population
Estimated number road fatalities per 100,000 population	1							
GNI per capita	-0.47	1						
% of paved roads	-0.12	0.39	1					
Population density	-0.19	0.04	0.00	1				
Population under 14 (%)	0.59	-0.70	-0.29	-0.11	1			
Population between 15-64 (%)	-0.58	0.62	0.26	0.14	-0.95	1		
Population over 65 (%)	-0.52	0.69	0.28	0.05	-0.92	0.74	1	
% of urban population	-0.41	0.67	0.20	-0.10	-0.68	0.68	0.56	1
Male life expectancy	-0.62	0.67	0.23	0.13	-0.76	0.77	0.63	0.71
Adult literacy	-0.62	0.56	0.22	0.00	-0.80	0.81	0.67	0.68
Number of hospital beds per 1,000 population	-0.30	0.46	0.19	0.00	-0.77	0.69	0.75	0.45
Number of physicians per 1,000 population	-0.50	0.60	0.20	-0.01	-0.85	0.76	0.85	0.67
Number of nurses per 1,000 population	-0.51	0.75	0.25	-0.03	-0.73	0.63	0.74	0.57
Number of vehicles per 1,000 population	-0.44	0.91	0.33	0.08	-0.77	0.57	0.85	0.67
Number of vehicles per km of road	-0.23	0.33	0.06	0.71	-0.31	0.37	0.20	0.41
Male smoking prevalence (%)	0.20	-0.34	-0.03	0.06	-0.03	0.09	-0.04	-0.18
Estimated number of deaths caused by violence per 100,000 population	0.44	-0.45	-0.13	-0.12	0.44	-0.40	-0.42	-0.27
Alcohol related deaths per 100,000 population	0.01	-0.11	0.01	0.01	-0.31	0.29	0.28	0.04
Voice and accountability	-0.43	0.71	0.21	0.06	-0.66	0.55	0.71	0.57
Political stability no violence	-0.33	0.65	0.14	-0.04	-0.62	0.55	0.62	0.51
Government effectiveness	-0.46	0.86	0.31	0.04	-0.70	0.62	0.71	0.62
Regulatory quality	-0.45	0.81	0.24	0.01	-0.68	0.60	0.67	0.62
Rule of law	-0.45	0.86	0.28	0.06	-0.67	0.60	0.66	0.60
Control of corruption	-0.41	0.88	0.28	0.00	-0.62	0.55	0.63	0.60

Table 5 (continued)

	Male life expectancy	Adult literacy	Number of hospital beds per 1,000 population	Number of physicians per 1,000 population	Number of nurses per 1,000 population	Number of vehicles per 1,000 population	Number of vehicles per km of road	Male smoking prevalence (%)
Male life expectancy	1							
Adult literacy	0.67	1						
Number of hospital beds per 1,000 population	0.38	0.67	1					
Number of physicians per 1,000 population	0.67	0.75	0.76	1				
Number of nurses per 1,000 population	0.53	0.64	0.69	0.73	1			
Number of vehicles per 1,000 population	0.64	0.57	0.55	0.64	0.71	1		
Number of vehicles per km of road	0.40	0.29	0.34	0.20	0.08	0.27	1	
Male smoking prevalence (%)	-0.11	0.04	0.18	0.04	-0.15	-0.41	0.09	1
Estimated number of deaths caused by violence per 100,000 population	-0.50	-0.31	-0.26	-0.35	-0.33	-0.46	-0.39	0.13
Alcohol related deaths per 100,000 population	-0.01	0.26	0.44	0.30	0.21	-0.05	-0.11	0.25
Voice and accountability	0.56	0.51	0.44	0.52	0.57	0.79	0.22	-0.23
Political stability no violence	0.52	0.48	0.48	0.48	0.57	0.69	-0.05	-0.16
Government effectiveness	0.66	0.54	0.44	0.57	0.68	0.87	0.27	-0.27
Regulatory quality	0.63	0.55	0.40	0.54	0.62	0.82	0.21	-0.28
Rule of law	0.66	0.51	0.42	0.53	0.64	0.85	0.27	-0.33
Control of corruption	0.64	0.47	0.36	0.49	0.64	0.83	0.21	-0.38

Table 5 (continued)

	Estimated deaths caused by violence per 100,000 population	Alcohol related deaths per 100,000 population	Voice and accountability	Political stability no violence	Government effectiveness	Regulatory quality	Rule of law	Control of corruption
Estimated number of deaths caused by violence per 100,000 population	1							
Alcohol related deaths per 100,000 population	0.42	1						
Voice and accountability	-0.35	0.03	1					
Political stability no violence	-0.48	0.02	0.77	1				
Government effectiveness	-0.49	-0.07	0.86	0.79	1			
Regulatory quality	-0.43	-0.04	0.89	0.79	0.95	1		
Rule of law	-0.55	-0.13	0.84	0.82	0.97	0.93	1	
Control of corruption	-0.50	-0.16	0.78	0.76	0.95	0.91	0.96	1

Notes: The pairwise correlation coefficients are always computed over all countries from the sample b for which both variables are available.

Table 6: Cross-country analysis

	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
	All countries sample a		**All countries** sample b						**Better quality data sample** sample c						**OECD countries** sample d	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
ln(GNI)	-1.124**	0.36	-0.219***	0.03	0.174*	0.10	-0.091	0.09	3.130**	1.26	0.975	1.24	1.339	1.21	7.566	7.15
ln(GNI^2)	0.054**	0.02							-0.174**	0.07	-0.044	0.07	-0.071	0.07	-0.389	0.38
ln(road paved)					-0.008	0.05	-0.033	0.05								
ln(urban pop)					0.234**	0.11	0.301**	0.13								
ln(pop density)					-0.045	0.04	-0.050	0.03			-0.070	0.06	-0.093	0.06		
voice & accountability					-0.114*	0.06	-0.068	0.07								
ln(alcohol)					0.246**	0.11	0.405***	0.13			0.394***	0.13	0.444***	0.15		
ln(nurses)					-0.231***	0.07	-0.235***	0.08			-0.174**	0.08	-0.169	0.11		
ln(literacy)					-0.322**	0.16	-0.062	0.17								
male LE					-0.026***	0.01	-0.009	0.01								
pop under 14											-0.034	0.02	-0.038*	0.02		
pop over 65											-0.071***	0.03	-0.056*	0.031		
Africa							0.451*	0.24					0.23	0.387		
Asia and Pacific							0.132	0.21					0.061	0.41		
Central-East Europe							-0.155	0.16					-0.272	0.26		
Middle East-North Africa							0.322	0.22					0.371	0.28		
Latin America -Caribbean							-0.263	0.23					-0.137	0.37		
constant	8.231	1.44	4.653	0.22	3.007	0.85	0.548	1.32	-11.394	5.70	-1.975	5.99	-3.050	5.55	-34.375	33.50
R^2	0.1983		0.2673		0.5243		0.6036		0.0929		0.4027		0.4581		0.0273	
Observations	166		112		112		112		70		70		70		28	

Notes: * Significant at 10%, ** Significant at 5%, *** Significant at 1%.
Sample a excludes the countries with more than 50 deaths per 100,000 pop.
Samples b, c and d exclude the countries with more than 50 deaths per 100,000 pop and the countries with less than 1 million inhabitants.

Table 7.A: Panel Data Analysis-All countries

	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
	(1)		(2)		(3)		(4)		(5)	
ln(GNI)	3.142***	0.313	1.631***	0.325	0.892**	0.380	2.209***	0.380	-0.397	0.449
ln(GNI^2)	-0.184***	0.017	-0.074***	0.019	-0.040*	0.022	-0.123***	0.021	0.027	0.026
pop between 15 and 64							-3.062***	0.878	1.591*	0.915
pop above 64							-5.995***	1.062	1.290	1.122
ln(pop density)							0.675***	0.212	-0.140	0.269
life expectancy							-0.039***	0.014	-0.026*	0.013
constant	-10.528	1.446	-5.681	1.437	-1.815	1.638	-4.432	2.066	5.636	2.556
Country-fixed effect	Yes		Yes		Yes		Yes		Yes	
Time-fixed effects	No		Yes		Yes		No		Yes	
Time-region interactions	No		No		Yes		No		Yes	
R^2 within	0.1251		0.226		0.388		0.228		0.433	
Observations	1411		1411		1411		1112		1112	
Countries	84		84		84		80		80	

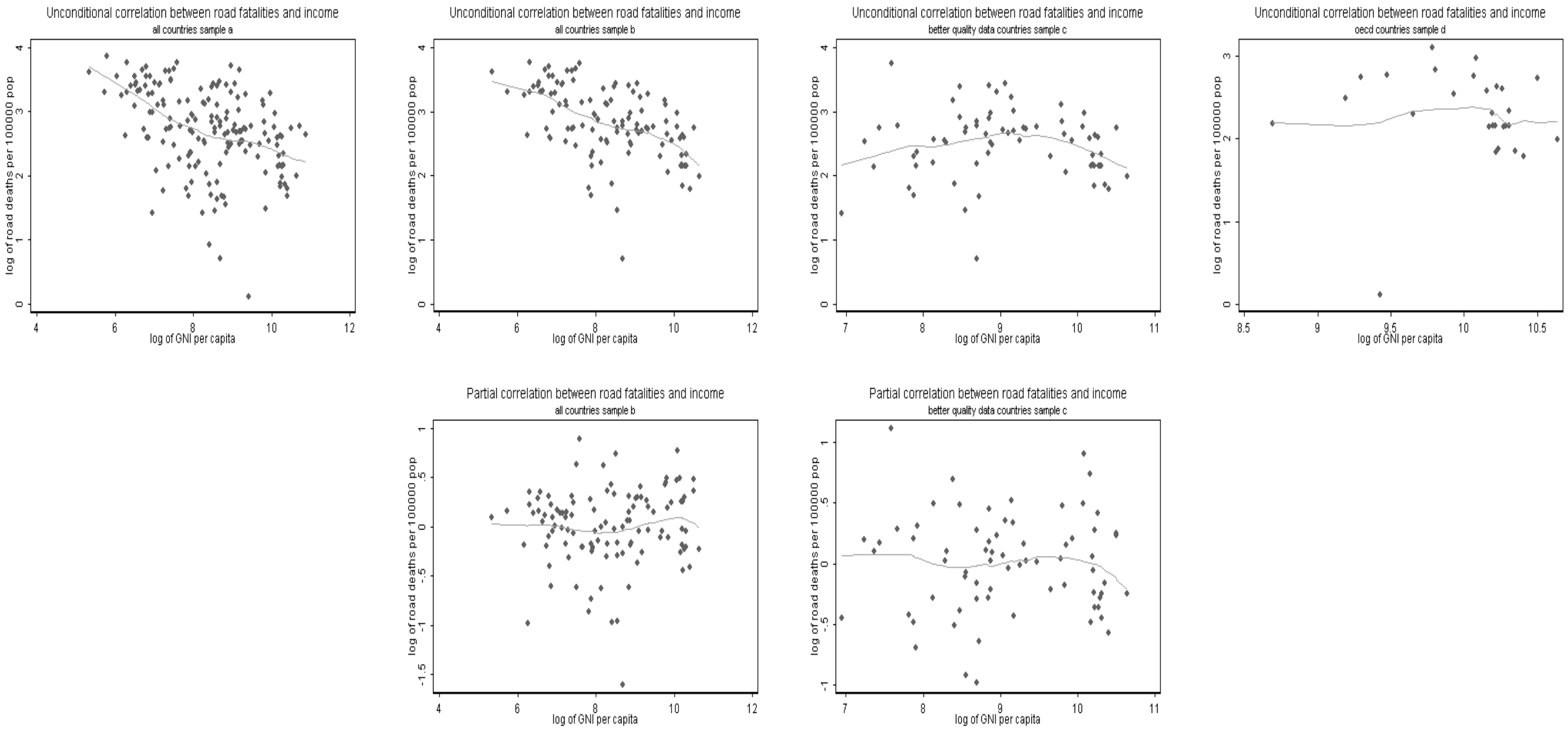
Notes: * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

Table 7.B: Panel Data Analysis-Different income group countries

	High income countries						Low and middle income countries					
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
	(1)		(2)		(3)		(4)		(5)		(6)	
ln(GNI)	2.615***	0.588	1.895***	0.666	-0.842	0.894	3.160***	0.558	1.166**	0.550	0.454	0.710
ln(GNI)2	-0.157***	0.030	-0.105***	0.035	0.0422	0.046	-0.185***	0.032	-0.41	0.033	-0.003	0.043
pop between 15 and 64					4.350***	0.854					-1.355	1.715
pop above 64					3.976***	0.769					-9.246***	3.367
ln(pop density)					-0.113	0.261					0.045	0.357
life expectancy					-0.094***	0.261					0.003	0.021
constant	-7.988	2.871	-5.820	3.221	11.009	4.367	-10.584	2.402	-3.916	2.312	1.217	3.827
Country-fixed effect	Yes		Yes		Yes		Yes		Yes		Yes	
Time-fixed effects	No		Yes		Yes		No		Yes		Yes	
R^2 within	0.501		0.529		0.610		0.043		0.211		0.276	
Observations	622		622		572		789		789		540	
Countries	25		25		25		59		59		55	

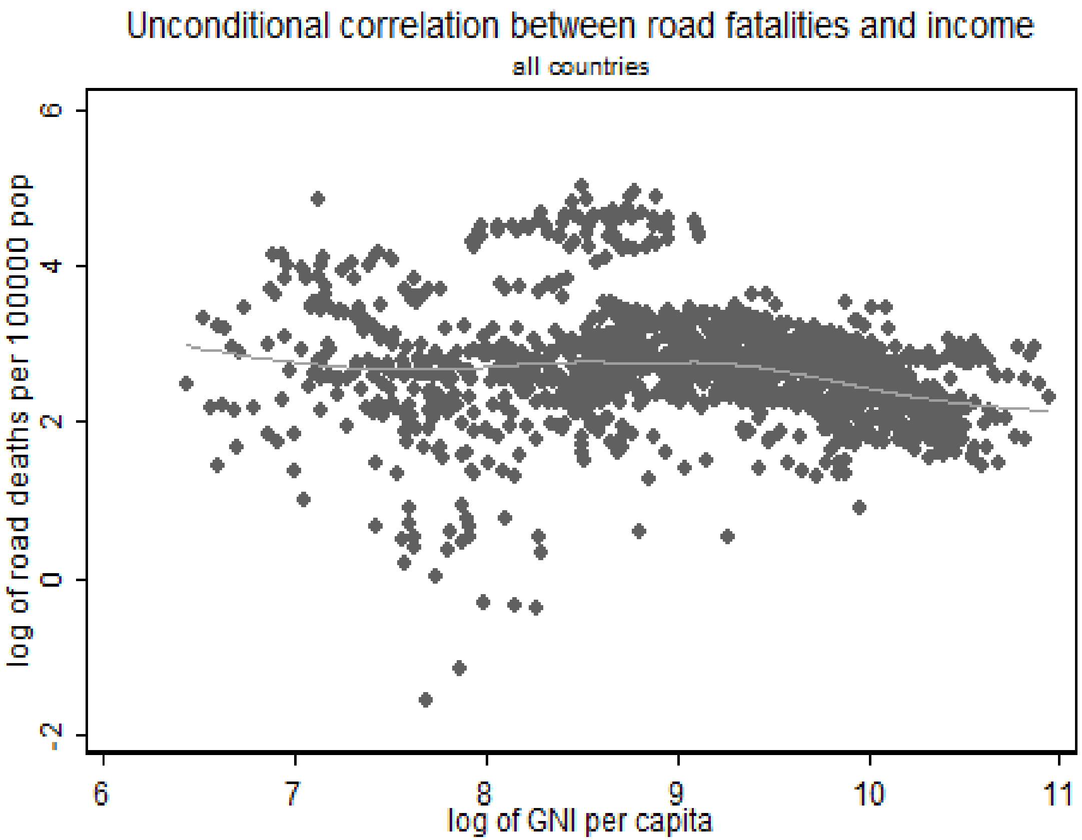
Notes: * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

Figure 1: Unconditional and partial correlation between road fatalities per 100,000 population and income



Notes: The figures showing the partial correlation between road traffic accident fatalities and income, once the effect of all other variables is netted out, were obtained as follows: we ran the regression in Table 6 (col. (3), for the all country sample and col. (6) for the better quality sample) without the GNI variable. These estimates are then used to predict fatalities. The predicted values are then subtracted from the observed fatalities which provides fatalities where the effect of all other variables is netted out.

Figure 2: Unconditional correlation between road fatalities per 100,000 population and income for all countries



Notes: The trend line was obtained through locally weighted regression.