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Determinants of Road Traffic Crash Fatalities across Indian States

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Abstract

Objective: This paper explores the determinants of road traffic crash fatalities in India. As potential factors, the analysis considers, besides income, the socio-demographic populationstructure, motorization levels, road and health infrastructure and road rule enforcement.

Methods: An original panel data set covering 25 Indian states is analyzed using multivariate regression analysis. Time and state fixed effects account for unobserved heterogeneity across states and time. Results: Rising motorization, urbanization and the accompanying increase in the share of vulnerable road users, i.e. pedestrians and two-wheelers, are the major drivers of road traffic crash fatalities in India. Among vulnerable road users, women form a particularly high risk group. Higher expenditure per policeman is associated with a lower fatality rate.

Conclusion: The results suggest that India should focus, in particular, on road infrastructure investments that allow the separation of vulnerable from other road users, on improved road rule enforcement and should pay special attention to vulnerable female road users.

JEL-classification: I18, O18, R41

Keywords

Transportation; traffic safety; vulnerable road users; road rule enforcement; urbanization; India.

Determinants of Road Traffic Crash Fatalities across Indian States[1]

1 Introduction

The World Health Organization (WHO) estimates that, annually, road traffic crashes cause over 1.2 million deaths and more than 25 million severe injuries worldwide (WHO, 2009). In 2020, road traffic injuries are expected to reach third in the ranking of the global burden of disease (Lopez *et al.*, 2006). Over 90% of the world's fatalities occur in low and middle income countries, putting road traffic fatalities on par with malaria deaths. Given that these fatalities are concentrated in the economically active population, reducing the number of road traffic injuries and fatalities could confer large welfare gains to households.

So far, the literature that has examined the causes of road traffic accidents has either focused on the cross-country variation in fatality rates and on the role of aggregate income as one of the major drivers of this variation or relied on small-scale case studies. Cross-country studies that rely on a single year of data (see e.g. Wintemute, 1985; Jacobs and Cutting, 1986; Söderlund and Zwi, 1995; Van Beeck *et al.*, 2000) almost all suggest that at very low levels of income, road traffic fatalities per population increase with income up to a certain threshold and then fall again. More recent studies that rely on panel data and thus can control for all time-invariant country-specific characteristics confirm this inverted u-shaped relationship (Kopits and Cropper, 2005, 2008; Bishai *et al.*, 2006). Moreover these studies have successfully worked out the mediating factors between income and road traffic accident fatalities at different stages of development. Other studies exploit, as we will do, the within-country variation in road traffic fatalities and thus reduce the potential bias through unobserved heterogeneity which might be

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a problem in cross-country studies (Traynor, 2008; La Torre *et al.*, 2007).

But all these studies typically focus on richer and highly motorized countries. In this paper we focus on India. India is an important case as it has one of the highest per capita traffic fatality levels in the world (WHO, 2009). More than 133,000 people died on Indian roads in 2010. According to police records about 85% of all fatalities are men, mainly between the ages of 30 and 59 and more than 40%, particularly women, are vulnerable road users, i.e. pedestrians or two-wheelers, with significant differences across states (Mohan, 2007, 2009). Unlike China, fatalities continue to increase. The social costs have been evaluated at 3.2% of GDP, a loss that inhibits economic and social development (Mohan, 2001).

Virtually no low income and less-motorized country has been successful in reducing the number of road traffic crash fatalities and injuries in the recent past. Traffic patterns in these countries are much more complex than those in high-income countries (Mohan, 2002), an issue we will take into account in our analysis. The reasons for this greater complexity are: (i) a large proportion of income-poor road users; (ii) a high proportion of vulnerable road users sharing the road with motorized vehicles; (iii) high population density in urban areas; (iv) a low enforcement level of road traffic rules and regulations; and (v) severe limitations on public resources available for roads and other infrastructure. The latter aspect is illustrated in Table 1 which shows that Germany, for instance, had, compared to India, a much higher income level at comparable rates of motorization.

[Table 1]

Figure 1a shows that in 2006 the number of registered motor vehicles in India was 50 times higher than in 1971. While two-wheelers represented one third of the total number of motorized transport in 1971, today they represent around 70% of the total. Figure 1b shows that there is indeed a strong correlation between fatalities per population and the number of vehicles per population, confirming the finding by Bishai *et al.* (2006) and Kopits and Cropper (2008), that in poor countries the rise of motorization that accompanies income growth is one of the most important forces in the increase in road accident fatalities per population; fatalities per vehicle decline in fact over time.

[Figure 1]

Garg and Hyder (2006) find a strong positive relationship between income and the road traffic crash fatality rate over a cross-section of Indian states, though this is relatively flat for the richest of these states. The authors speculate that the plateau is related to increased investment in road safety measures, regulations, and public transport. However, none of these hypotheses has been examined empirically. Our study makes an attempt to close this gap by exploiting variations across time and Indian states to disentangle the roles of various factors related to the road accident fatality rate in general and by type of road user in particular.

2 Method

2.1 Conceptual framework

We focus on four different sets of factors; factors associated with the socio-demographic population structure, with the motorization level, with the road and health infrastructure and with institutional quality. In addition we include income that may play a role in conjunction with these factors.

Among the socio-demographic factors we include gender, education, life-expectancy, urbanization, population density and religion since we assume that these factors influence risk attitude, risk exposure and risk knowledge and via these channels road traffic accident fatalities. Individual income and employment status can be seen as further intermediate variables through which socio-demographic characteristics act on risk attitude, risk exposure and risk knowledge. Income and employment determine the frequency of traveling, the means of transport, the availability of safety devices and the relative costs of physical and human damage.

Motorization should matter through the number of registered vehicles and the vehicle mix. In poorer countries the diversity of vehicles sharing the same road leads to high differences in speed between the various road users, which in turn may increase the number of accidents compared to a country with a more homogenous group of road users. To account for road infrastructure we include some characteristics of the road network. We consider also health care supply as the quality of trauma and medical care may matter for the chances of accident victim survival. Moreover, the quality and accessibility of health facilities may also have an indirect impact on the risk attitude of road users. Regarding the institutional factors, we mainly focus on the enforcement of road traffic rules and regulations.

There are good reasons to believe that income affects road traffic fatalities through all four transmission channels. First, economic development usually leads to increased motorization levels and urbanization. Second, a higher national income will allow the government to invest more resources in the quality and quantity of road and health infrastructure. Moreover, resources allocated to the police may also increase with national income. On the individual level income should matter because, with higher income, road users can also afford more and better safety devices such as better-quality vehicles and helmets. Finally, people's risk attitude and exposure to risky situations is likely to be affected by income. The more of the relevant transmission channels are captured by the empirical analysis, the less we expect income to be significant in our analysis.

Figure 2 summarizes the conceptual framework graphically. Our framework is closely related to the systems approach used by the Global Road Safety Forum, an international initiative for global road safety (www.globalroadsafety.org). The systems approach is inspired by the so-called 'Haddon Matrix' which distinguishes three main factors: human, vehicles and equipment and the environment (including the legal framework) that interact over three time windows – pre-crash, crash, and post-crash – to produce or prevent road traffic accident fatalities or injuries.[2]

[Figure 2]

2.2 Data

Our data set covers 21 Indian states and four Union Territories (UTs) over the period 1989 to 2006.[3] However, for some of our analysis we stick to the period

[2] This distinction of factors related to humans, vehicles and roads and enforcement has also been adopted by the WHO (2010) and, in a similar form, by the World Bank (2009).

[3] Before 2000, there were 25 states and 7 Union Territories. We had to exclude three states because these were later split up into several states. We also excluded the UT of Lackshadweep because of its very small size.

1996 to 2006 and 24 instead of 25 state/UT observations as the information regarding other variables is incomplete for earlier years and one particular state. The variables have been drawn from many different sources. The details are given in Table A1 (appendix). The number of road traffic fatalities per population and its components pedestrian, two-wheeler and four-wheeler fatalities are taken from the National Crime Records Bureau (NCRB). Socio-demographic information is based on census data.[4] State level income is measured by the per capita Net State Domestic Product (NSDP) using 1993 prices published by the National Statistics. Road infrastructure, motorization levels and the vehicle mix were obtained from the Ministry of Road Transport and Highways. Information on road infrastructure is unfortunately missing for many states and years. Information on health care supply, i.e. the number of hospitals and dispensaries, is drawn from the 'Center for Enquiry into Health and Allied Themes' database. We completed this information with the 2001 Census state fact sheets. However, here again the time period covered is a bit shorter than for most of the other variables. Finally, data from the NCRB was again used to compute different proxies of road rule enforcement, i.e. expenditure per policeman, the number of policemen per population and the number of cases under investigation per policeman. We have to assume that traffic police expenditures are proportional to total police expenditures.

As discussed in detail in Garg and Hyder (2006), the under-reporting of fatalities might be high in some of the states. However, in the absence of any reliable information that could help to adjust these numbers between states and across time, we refrain from making any corrections. Moreover, it was not possible to find data on all the aspects discussed in our conceptual framework. For instance, the age distribution is not available on a per state basis for our observation period. The same applies to the quality of health services. Hence, there is a clear trade-off between the level of spatial disaggregation and the length of the observation window on the one hand and the exhaustiveness of the data set on the other.

[4] To fill in the missing information for years for which no census data is available, we imputed values based on a geometrical extrapolation.

2.3 Empirical specification

To analyze our data, we use a two-way fixed effects model:

$$\ln(fatalities_{st}) = \alpha + \beta_1 \ln NSDP_{st} + \beta_2 (\ln NSDP_{st})^2 + X'_{st}\delta + \mu_s + \mu_t + \varepsilon_{st}, \quad (1)$$

where $\ln(fatalities_{st})$ stands for the log road traffic fatalities per 100,000 population in the State (or UT) s in period t. Alternatively we use pedestrian, two-wheeler and four-wheeler fatalities. NSDP stands for net state domestic product per capita in 1993 Rupees (income per capita hereafter), which we introduce in linear and squared form to account for possible non-linearities. The vector X_{st} stands for the set of potential determinants discussed above. Year effects are denoted μ_t. They control for all time-specific effects that are uniform across states such as the general trend in the safety level of vehicles or general changes in traffic regulations. State level fixed effects are denoted μ_s. They account for all the heterogeneity between states that is constant over time such as general weather conditions, the topography and cultural attitudes and norms but also under-reporting as long as this is constant over time. The test statistics that guided the choice of the model are briefly discussed below. We always estimate the model first with income alone and then subsequently introduce all other potential determinants.

3 Results

Table 2 shows the mean and standard deviation of all variables in our data set, including the within and between state variation. The sample mean fatality rate is 9.7 deaths per 100,000 population (1994 to 2006). Across states this rate varies from about 3 (Assam in 1996) to 21 (Goa in 2006). Over time the mean increased from 7.4 in 1994 to 12 in 2006. For India as a whole, Kopits and Cropper (2005) projected this rate to rise to 24 by 2042. The motorization level also varies substantially across states and time. In 1994 Tripura had 104 (min) vehicles (any motorized vehicle, including two-wheelers) per 10,000 inhabitants whereas Chandigarh had 4,417 (max). In 2006 the minimum increased to 189 (Arunachal Pradesh) and the maximum to 5,862 (Chandigarh). Figure 3 shows that fatalities increase strongly with income but at a decreasing rate. For the richest states the relationship is flat and even starts to turn negative, suggesting a turning point similar to what cross-country studies found. This is further discussed below. Conversely, fatalities per vehicle are somewhat negatively correlated with income. In our regression analysis we control for vehicles per population (motorization), hence the estimated effects of the other explanatory variables reflect first of all their effect through fatalities per vehicle.

[Table 2 and Figure 3]

Table 3 shows multivariate regression results for road traffic fatalities per population. In the model in column (1) we only include the log of income and the log of income squared. We then successively introduce state fixed effects (col. (2), time effects (col. (3) and all other control variables (cols. (5) and (6)). Column (5) is a simple OLS regression without fixed effects, allowing us to also focus on between-state differences. Column (4) shows, in addition, a regression on a larger sample including, i.e. all states and using also those state-year observations in which one or several of our control variables are missing. Column (7) in turn shows a regression in which we use a balanced panel, using 20 states/UTs observed over 9 years. Prior tests indicated that state fixed effects are indeed required (Preusch-Pagan test) and that fixed effects (FE) are appropriate whereas random effects are not (see results of Hausman tests in Table 3). Modified Wald tests reject the homoskedasticity of our models (not reported), and hence we compute and show robust standard errors.

[Table 3]

Column (1) suggests an inverted u-shaped fatalities-income relationship with an estimated turning point, i.e. the income threshold at which fatalities start to decline, of more than Rs. 100,000. This turning point is shifted to the left, as state fixed effects and time effects are introduced. If both are considered (col. (3)) the estimated turning point is Rs. 9,971. However, the key finding is that the unconditional relationship is concave with an estimated turning point that is situated at the top end of the income distribution in our sample. This can also be seen in Figure 5a. Correspondingly, a simple F-test (not reported) does not reject the quadratic form of the income effect. These findings are confirmed if we use the larger sample. If we add further explanatory variables to the model in column (3) and first leave out the state and time fixed effects, the inverted u-shaped fatalities-income relationship is still significant. If we introduce time and state fixed effects together with all control variables (col. (6)), income looses its significance, but we now find a significant positive effect for urbanization and literacy and a significant negative effect for expenditure per policeman. The other enforcement variables turned out to be insignificant and hence, we not kept in the model. In column (5) motorization has a significant positive effect on the number of fatalities whereas the share of four-wheelers relative to the share of two-wheelers (controlling for motorization) has a negative effect. These effects still have the same signs in column (6), but are not anymore statistically significant once state fixed effects are introduced. If we just rely on the balanced panel, which is smaller by 65 observations, the three effects associated with urbanization, literacy and expenditure per policeman are still significant but of a even higher magnitude. Life expectancy was always insignificant and is also only available for a very short and selected panel. We also checked whether multicollinearity posed a problem. Although some of the independent variables do indeed show relatively high pairwise correlation coefficients (e.g. urbanization and population density (0.85), urbanization and motorization (0.86) and income and literacy (0.61), the regression results are surprisingly robust to the inclusion/exclusion of some of these variables.

We now turn to fatalities by road user category. Figure 4a shows the trends over time. The number of pedestrian fatalities per population is more or less constant. Fatalities per population of two-wheelers strongly increases and fatalities per population of four-wheelers fell until 2002 and then increased again quite substantially. As mentioned above, almost 50% of all fatalities concern pedestrians and two-wheelers. Figure 4b shows that the relative importance of each of these categories varies significantly across states. Delhi, with more than 2,000 fatalities per year, is the only state in which the fatalities of pedestrians alone dominate the fatality rate: car, truck and bus occupants least represented.

[Figure 4 and Table 4]

In Table 4 we run similar regressions than in Table 3 but instead of using the overall fatality rate we use the number of pedestrian (cols. (1)-(3), two-wheeler (cols. (4)-(6) and four-wheeler deaths (cols. (7)-(9). We again control for time effects, but leave out state fixed effects. The fixed effects regressions did not provide robust results leading us to conclude that there is not much to learn from the within state variation and hence we focus now uniquely on the pooled sample.[5] The income effects alone (cols. (1), (4) and (7) indicate an exponential growth of pedestrian and two-wheeler fatalities with income and a concave increase of four-wheeler fatalities. This is also illustrated in Figure 5. The turning point for four-wheeler fatalities is situated at about 12,500 Rs. per capita per year (1993 prices), which is significantly lower than the turning point for all categories of fatalities taken together (ref. col. (2), Table 3), implying that in the process of income growth four-wheeler fatalities start to decline earlier than pedestrian and two-wheeler fatalities. The results suggest that the pedestrian fatality rate increases with urbanization and slightly decreases with population density (holding urbanization constant). Moreover, pedestrian fatalities increase with higher literacy and decrease with the share of the male population. Motorization and the share of four-wheelers is are both positively associated with road traffic fatalities, implying that controlling for urbanization and population density, an increased motorization and an increased share of four wheelers increase pedestrian fatalities. However, the two latter effects are not statistically significant.

Two-wheeler fatalities strongly increase with the motorization level and, surprisingly decline with the share of four-wheelers. They also decline, quite plausibly, with expenditure per policeman with the share of males. Lastly, the estimates for four-wheeler fatalities suggest a decline with urbanization and the share of four-wheelers. This seems to suggest that in urbanized areas with a large number of four wheelers, vehicles are slower and hence, four-wheeler fatalities are less likely. Literacy now has a negative effect. Hence, taken all results together, literacy increases pedestrian fatalities, has no impact on two-wheeler fatalities and reduces four-wheeler fatalities. These effects are robust to the inclusion/exclusion

[5]Although Breusch-Pagan tests did not reject the use of fixed effects, the test results were less clear-cut than those in Table 3.

of income (except in col. (8)).

[Figure 5]

To see whether differences in religion can explain differences in fatality rates, we use the state fixed effects from Tables 3 and 4 and regress these on the religious composition in each state/UT, i.e. we treat the religious composition as a quasi fixed factor as these shares change only very slowly over time. In Table 5 we only report the regression coefficients, the R^2 as well as a joint F-Test. Note that religious composition is not available for all observations covered by the regressions in Table 3. The joint F-test suggests that religion matters. For instance, whereas the proportion of Muslims seems, on average, to increase the fatality rate (although the effect is not significant), the proportions of Christians and in particular of Buddhists and Jains seem to reduce the fatality rate. If we run these regressions alternatively on pedestrian, two-wheeler and four-wheeler deaths, we find at least for two-wheelers very similar results. The larger the share of these latter two groups, the lower the fatality rate. In general, religion can explain between 50% and 80% of the total variance in the fixed effects.

[Table 5]

4 Discussion

The role of aggregate income

The weakly concave relationship between road traffic accident fatalities and income is coherent with the inverted u-shaped relationship that other studies using cross-country panel data have found before (see e.g. Kopits and Cropper, 2005; Bishai *et al.*, 2006). Given India's GDP, we expect most Indian states to still be on the rising branch of this curve. And indeed, the turning point we identify is reached only by the richest states and towards the end of the observation window. When we control for time and in particular for country fixed effects, the income effect almost vanishes, implying that all states follow a similar temporal pattern, on different levels, that is strongly related to income growth. If we break down fatalities by type of road users, we find pedestrian fatalities and two-wheeler fatalities to steadily increase with income, whereas four-wheeler fatalities first increase and then decline. This can best be seen in Figure 5. The effect of motorization on four-wheeler fatalities is in fact weakly negative. This is not surprising in the Indian context, where rising motorization is accompanied by urbanization, an increased population density and a steady increase in vulnerable road users, i.e. pedestrians and two-wheelers (see also Nantulya and Reich, 2003; Ameratunga *et al.*, 2006). Paulozzi *et al.* (2007) in fact shows that fatalities are highest during a critical transition to motorized travel, when many pedestrians and other vulnerable road users share the roadways with many motor vehicles. This observation is consistent with our findings. Likewise, Kopits and Cropper (2008) emphasize that a higher population density and urbanization results in an increase in pedestrian activity and hence higher pedestrian fatalities (per vehicle). Traynor (2008) shows similar evidence for Ohio state (USA). Our results differ just in one respect: holding urbanization constant pedestrian fatalities slightly decline with population density. A plausible explanation might be that a higher density is associated with a lower average speed of vehicles. Our multivariate analysis suggests that the decline of four-wheeler fatalities is indeed mainly driven by increased urbanization and in the richer states in more recent years and a higher share of four wheelers in the traffic mix which may slow down the average speed (Table 4). Taken together, the estimates suggest that if the urbanization rate increases by 1%, the four-wheeler fatality rate per 100,000 of the population decreases by about 0.30%, whereas the pedestrian fatality rate increases by about 1%. This is an important finding.

Road and health infrastructure

Since there is not much data available, the role of road and health infrastructure was difficult to study. We do not find any effect related to the road density (length per km^2) or the quality of roads (results not shown). We think this has different reasons. First, these variables are probably poor measures of road infrastructure and hence are probably better captured by urbanization. Second, better roads may have contrasting effects on road safety. On the one hand they may increase road safety e.g. through the absence of potholes and a better separation of vulnerable and non-vulnerable road users. On the other hand, as Keeler (1994) pointed out, a better road infrastructure may also lead to faster driving and thus off-setting some of the positive effects of improved road infrastructure. In the literature this is known as the 'Peltzman hypothesis'. Peltzman (1975) theorized that a road user is likely to be concerned with both the time the journey takes and his/her safety. Hence, if roads become safer, the motorist will likely offset the higher level of safety with faster driving, so that some of the enhanced safety is used to provide a faster trip. Such effects might be particularly relevant in a context like India, where the enforcement of road rules is low.

For richer countries, Bishai *et al.* (2006) have identified lower injury severity and better post-injury medical care as one of the main mediating factors that reduce road accident fatalities (see also Jacobs and Cutting, 1986; Van Beek *et al*, 2000; Kopits and Cropper, 2008). As we mentioned above, we only found little and incomplete information on health infrastructure by state and year and hence we could not analyze this relationship quantitatively. However, given that the number of hospitals per population rather decreased than increased over time (Table 2), we speculate that this did not contribute to bring fatalities down, even though from our field work we know that the main problems are often not hospital care per se, but rather the quality of first-aid on the spot and that many death events could be prevented by getting casualties to the clinic faster.

Motorization and vehicle mix

With respect to motorization and the vehicle mix, we find distinct patterns for different categories of fatalities. Pedestrian fatalities seem to increase with the general level of motorization and with the share of four-wheelers, although these effects are statistically not significant in our regressions. For two-wheelers we find a strong positive effect associated with the level of motorization and a negative effect associated with the share of four-wheelers, which in turn suggests, plausibly, that many fatal accidents actually happen between two-wheelers. For car occupants and other four-wheelers, we find only a weak and, if any, rather negative effect of increased motorization. The share of four-wheelers significantly reduces four-wheeler fatalities, probably, because a higher share of four-wheelers, holding constant the level of motorization, means more traffic jams and a lower average speed.

Institutional quality

A very robust finding of our analysis is the significant negative impact of expenditure per policeman on road traffic accident fatalities. This effect is significant in almost all specifications. An increase in expenditure per policeman by 1% induces a decline of the fatality rate by about 0.15%. This is a sizeable effect. We take this as an indication that a better paid and equipped police is more effective in enforcing road traffic rules and that a higher enforcement rate has a direct effect on the frequency of road traffic accident fatalities.

Socio-demographic characteristics

The effects related to urbanization and population density have already been discussed together with income and motorization, hence we focus now on the population composition by gender, education and religion. A higher share of women seems to be associated with more two-wheeler and pedestrian fatalities. This is also plausible, as women disproportionately walk, since they less often have a driving license and because they travel on average shorter distances as, among other things, their labor force participation is lower. Moreover, and maybe even more importantly, helmet usage is very low among female two-wheelers (drivers and passengers). A representative survey among two-wheelers that we conducted from July to September 2011 in Delhi revealed that 74% of men but only 31% of women regularly wear a helmet.

Quite unexpectedly we find a quite robust positive effect of literacy on pedestrian fatalities and a negative effect on four-wheeler fatalities. The negative effect on pedestrian fatalities may surprise, as one would assume that general formal education is correlated with, for example, awareness of road traffic laws and regulations, knowledge of traffic signs or offences and related penalties. However, our experience in the Indian context seems to show that this is not necessarily true. A small survey that we undertook in Delhi in 2010 showed that road traffic-related knowledge was in general very low and uncorrelated with formal education. In that survey we asked road users about the meaning of road signs such as 'stop', 'no parking', or 'pedestrian crossing'. The results were quite surprising. Indeed, out of the ten questions asked, 27% of the 250 persons interviewed could not explain the meaning of any of the presented road signs, and 80% of them had more than six wrong answers. Even professional drivers such as taxi and cycle rickshaw drivers did not perform better in this test. In that sense it is almost surprising that we find a negative effect of education on four-wheeler mortality. It may capture vehicle quality or access to health care, but to confirm such hypotheses more micro evidence is necessary to find out how education relates to risk attitude, exposure and knowledge. Fosgerau (2005) and others have argued that better education and hence a higher income may increase the perceived value of time and decrease the 'real cost' of fines (see also Polinsky and Shavell, 1979; Blomquist, 1986; Boyer and Dionne, 1987). Better educated and hence richer individuals may, therefore, drive faster, which will increase their chance of being involved in an accident.

Our regression analysis identified religion as an important driver of cross-sectional differences in the fatality rate. Although we do not find very robust differences between Hindus and Muslims, the two main religious groups, we find that the share of Christians and in particular Buddhists and Jains seem to reduce the fatality rate. Jains reject the caste system which may influence their behavior towards vulnerable road users. They also explicitly prescribe a path of non-violence towards all living beings which could also characterize their behavior as road users.

5 Conclusion

A strong increase in motorization levels coupled with urbanization are the general drivers of road traffic crash fatalities across Indian states. This is partly due to the increased number of vulnerable road users, i.e. pedestrians and two-wheelers. Some of the richer states can expect that they will soon have reached the turning point after which fatalities per population will decline again with further income growth. To accelerate this process, our analysis highlights the following areas where policy intervention can be particularly effective. First, our study suggests that increased enforcement of road traffic rules can lower road traffic crash fatality rates. In our sample, if mean expenditure per policeman is increased by 10%, the fatality rate is reduced, for instance, by 2%. Second, urbanization strongly increases pedestrian fatalities. These can possibly be best prevented by clearly separating pedestrians and vehicle users, for instance through the construction of side walks, traffic lights and properly indicated bus stops. Third, we find a clear female bias in the mortality among vulnerable road users. Hence, awareness campaigns should particularly target women, for instance to promote the use of helmets on motorbikes. Fourth, we find that certain religious groups are less involved in accidents than others. Although we cannot control for the intensity of road use, this suggests that road users behavior may differ across religious groups and that awareness and behavioral change campaigns should be targeted at those groups with more involvement. We think our findings may also apply to other countries, in particular those that are also still in the phase where fatalities per population are increasing, not decreasing, with income. More micro data covering information about road users risk attitude, risk knowledge and risk exposure would further enrich this kind of analysis.

Appendix

[Table 1A]

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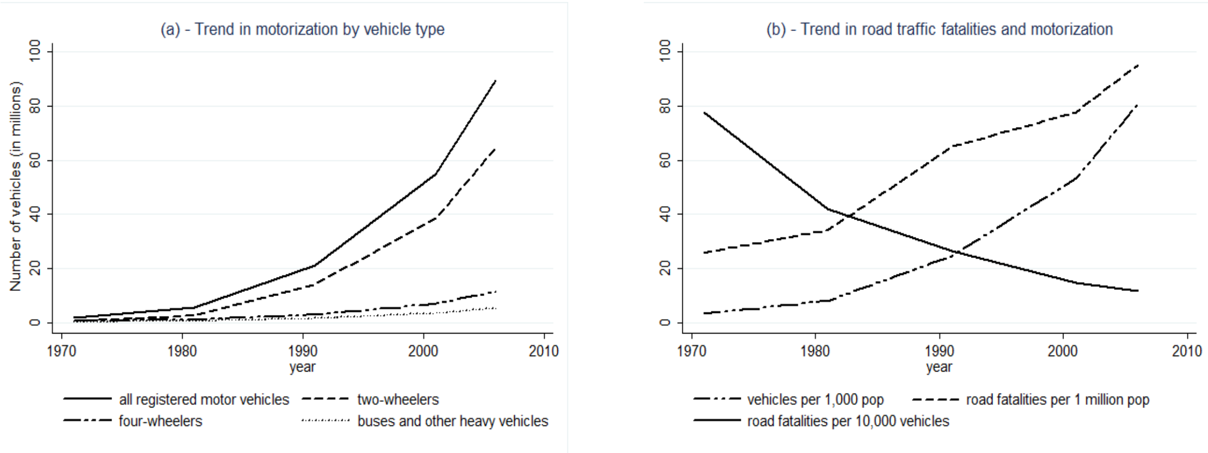
Tables and Figures

Table 1: Same motorization level, different income

	Year	Motor vehicles per 1,000 population	GDP per capita in 2005 Intl $ PPP
India	2005	73	588
Germany	1960	73	7,092

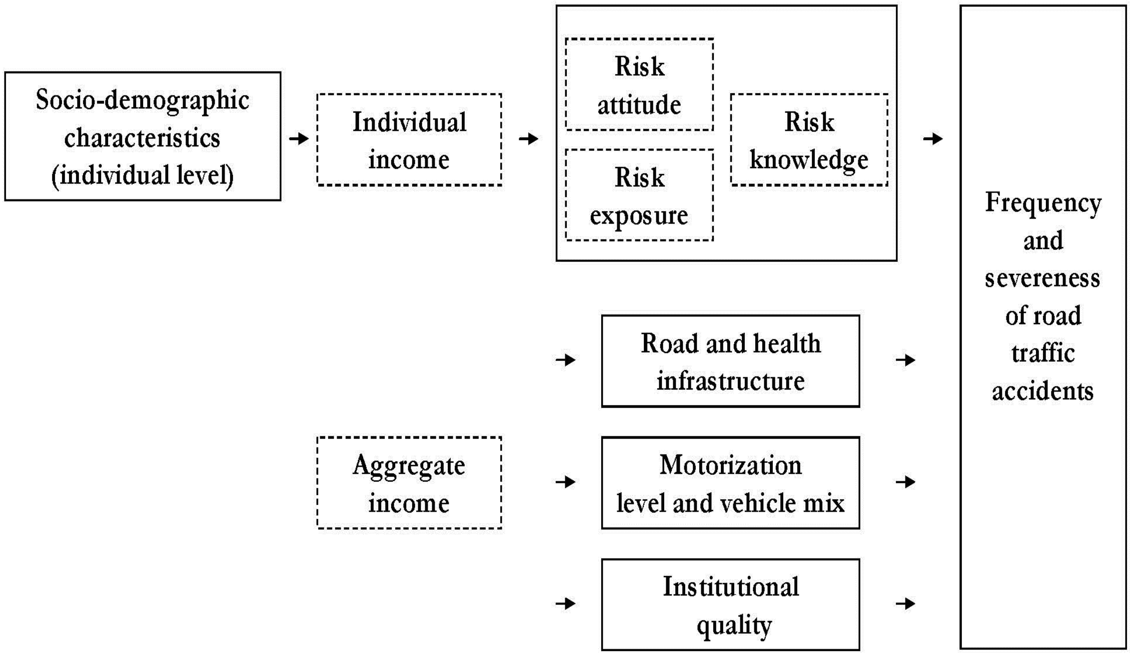
Sources: World Development Indicators, World Bank (2010).

Figure 1: Trends in motorization and road traffic fatalities in India, 1971 - 2006



Source: See Table A1.

Figure 2: Conceptual framework



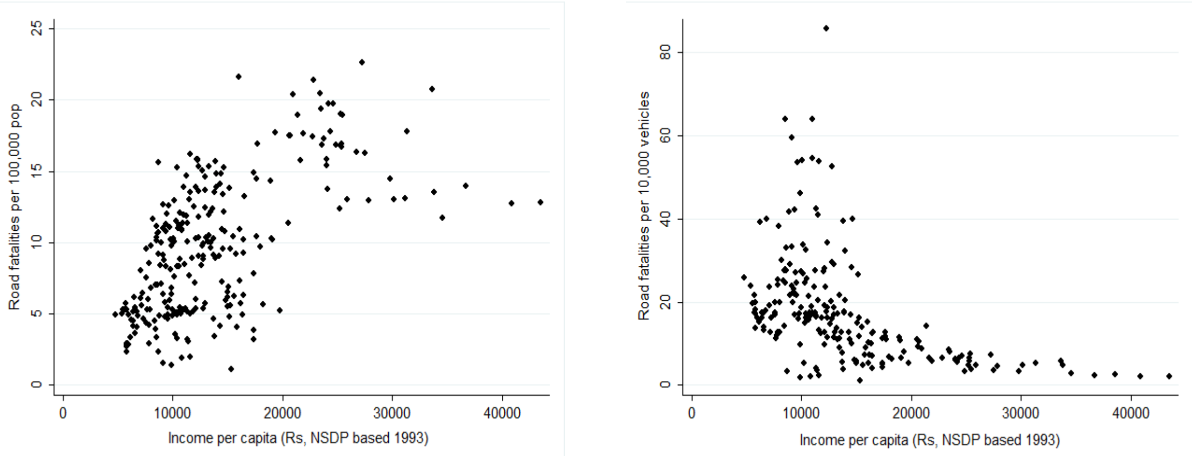
Source: Own representation.

Table 2: Descriptive statistics of variables used, 1994-2006

Variables	**Observations** N	n	T-bar	**Mean** overall	1996	2006	**Standard Deviation** overall	between	within
ROAD TRAFFIC ACCIDENT FATALITIES									
Fatalities per 100,000 pop	245	24	10.21	9.65	8.90	12.19	4.99	4.57	2.09
Pedestrians deaths per 100,000 pop⋆	199	24	8.29	1.23	1.26	1.28	1.59	1.34	0.89
Two-wheeler deaths per 100,000 pop⋆	199	24	8.29	2.52	1.89	3.64	2.54	2.41	1.04
Four-wheeler deaths per 100,000 pop⋆	199	24	8.29	5.53	5.32	6.43	3.00	2.66	1.60
INCOME									
NSDP per capita (Rs, based 1993)	245	24	10.21	13,145	10,677	17,894	6,701	6,325	2,835
SOCIO-DEMOGRAPHIC STRUCTURE									
Total population (in thousands)	245	24	10.21	27,600	27,000	31,900	29,100	29,400	2,587
Male ratio (%)	245	24	10.21	51.93	51.83	51.92	1.72	1.77	0.31
Urban population (%)	245	24	10.21	33.35	30.58	36.61	21.31	22.08	1.70
Population density (pop per km^2)	245	24	10.21	1,010	691	1,431	2,251	2,320	337
Life expectancy (years)	132	13	10.15	64.49	63.37	67.30	4.13	3.85	1.61
Literacy rate (%)	245	24	10.21	69.73	64.87	76.53	11.10	9.95	4.82
Hinduism (%)	194	19	10.21	67.50	67.24	65.92	26.08	26.82	2.23
Islam (%)	194	19	10.21	9.53	9.55	9.84	8.89	8.87	1.48
Christianism (%)	194	19	10.21	15.05	14.90	13.13	24.48	25.45	1.32
Buddhism and Jain (%)	194	19	10.21	2.36	1.60	3.41	5.24	6.71	0.52
ROAD AND HEALTH INFRASTRUCTURE									
Total road length per km^2	139	23	6.04	1.38	1.86	2.14◇◇	2.35	3.89	0.27
Hospitals per 100,000 pop	93	12	7.75	81.54	91.33	57.48◇◇	50.72	40.23	32.05
MOTORIZATION LEVEL									
Vehicles per 1 million pop	245	24	10.21	91,741	57,447	141,022	107,295	110,546	31,835
Two-wheelers (%)	245	24	10.21	66.73	65.74	68.27	15.22	16.20	3.16
Four-wheelers (%)	245	24	10.21	18.45	17.18	20.31	10.51	11.85	2.14
INSTITUTIONAL QUALITY									
Expenditure per policeman (Rs)	245	24	10.21	102,843	88,607	97,493	86,666	39,163	77,961
Total cases per policeman	245	24	10.21	3.53	4.35	2.74	4.26	3.54	2.41
Policemen per 100,000 pop	245	24	10.21	294	300	246	225	228	56

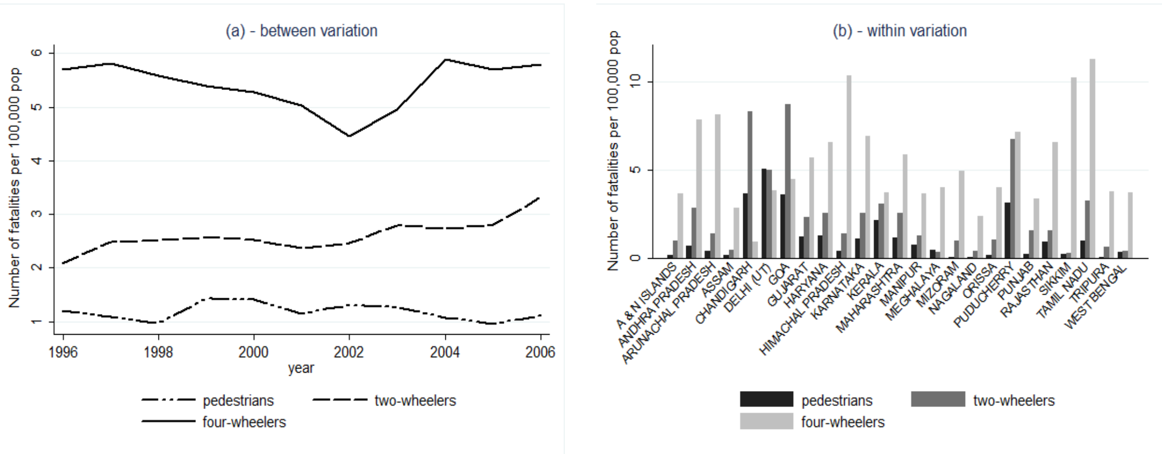
Notes: T-bar is the average number of years per state (N/n). We dropped one state from the sample, as for this state most of the other variables are not available, hence, this table just shows the statistics for the sample most of our analysis relies on. Some variables are not available for all states. Moreover for some states there are missings for some of the variables in particular years. ⋆ Information only available for the period 1996 to 2006 (1998 and 2001 missing).

Figure 3: Income per capita and road traffic accident fatalities per population and vehicle in India, 1994-2006



Source: See Table A1.

Figure 4: Road traffic accident fatalities by type of road user across time and states



Source: See Table A1.

Table 3: OLS and FE regressions of road traffic accident fatalities per population, 1994-2006

Dependent variable: ln (road deaths per 100,000 pop)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln (income)	1.757***	2.569***	1.596*	1.677*	2.349***	0.226	0.298
	(0.001)	(0.007)	(0.071)	(0.053)	(0.000)	(0.864)	(0.916)
ln (income)^2	-0.189*	-0.400**	-0.347**	-0.349**	-0.368***	-0.061	-0.058
	(0.053)	(0.018)	(0.035)	(0.023)	(0.001)	(0.817)	(0.918)
ln (percentage of urban population)					-0.076	1.961**	2.735**
					(0.519)	(0.016)	(0.048)
ln (population density)					0.031	-1.145	-1.574
					(0.446)	(0.486)	(0.542)
ln (male ratio)					-0.034	0.009	-0.006
					(0.377)	(0.514)	(0.736)
ln (literacy rate)					-0.110	1.428***	2.145***
					(0.720)	(0.004)	(0.006)
ln (expenditures policeman)					-0.121*	-0.132***	-0.178***
					(0.059)	(0.003)	(0.003)
ln (vehicles per 1 million population)					0.180*	0.145	0.013
					(0.065)	(0.744)	(0.984)
Share of registered four-wheelers†					-1.005***	-0.006	0.118
					(0.000)	(0.996)	(0.947)
Constant	-1.043	-1.720	0.638	0.399	-0.972	-4.185	-5.699
	(0.114)	(0.149)	(0.624)	(0.759)	(0.603)	(0.808)	(0.834)
State fixed effects	No	Yes	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	Yes	No	Yes	Yes
Balanced sample	No	No	No	No	No	No	Yes
Hausman test: Prob>chi^2		0.000	0.105	0.105		0.000	0.010
Income turning point (Rs)	104,361	24,810	9,971	8,973			
Observations	245	245	245	323	245	245	180
R-squared overall	0.328				0.433		
R-squared within		0.114	0.243	0.229		0.364	0.370
Number of id		24	24	25	24	24	20

Notes: P-values in parentheses, *** Significance at 1%, ** Significance at 5%, * Significance at 10%.
† Four-wheelers covers cars, jeeps, bus, trucks, tractors and tempos. Share of two and three-wheelers is the reference category.

Table 4: OLS regressions of road traffic accident fatalities per population by type of road user, 1996-2006

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable (in ln)	Pedestrian fatalities per 100,000 pop			Two-wheeler fatalities per 100,000 pop			Four-wheeler fatalities per 100,000 pop		
ln (income)	0.272	-0.964	-0.472	-0.280	0.463	0.578	6.335***	6.553***	6.685***
	(0.791)	(0.341)	(0.639)	(0.781)	(0.504)	(0.411)	(0.000)	(0.000)	(0.000)
ln (income)^2	0.285	0.227	0.172	0.363*	0.012	-0.010	-1.260***	-1.200***	-1.238***
	(0.139)	(0.274)	(0.396)	(0.062)	(0.928)	(0.943)	(0.000)	(0.000)	(0.000)
ln (percentage of urban population)		1.262***	1.020***		0.096	0.082		-0.309**	-0.279*
		(0.000)	(0.000)		(0.567)	(0.655)		(0.016)	(0.066)
ln (population density)		-0.140**	-0.148***		-0.046	-0.045		-0.006	-0.002
		(0.038)	(0.008)		(0.456)	(0.475)		(0.900)	(0.964)
ln (male ratio)		-0.080***	-0.083***		-0.089***	-0.088***		0.008	0.002
		(0.001)	(0.008)		(0.001)	(0.003)		(0.817)	(0.961)
ln (literacy rate)		1.483***	1.892***		0.185	0.201		-0.844**	-0.860***
		(0.007)	(0.000)		(0.659)	(0.657)		(0.012)	(0.010)
ln (expenditures per policeman)		-0.266	-0.034		-0.297***	-0.262***		0.024	0.074
		(0.105)	(0.841)		(0.004)	(0.009)		(0.841)	(0.503)
ln (vehicles per 1 million population)		0.077	0.143		0.512***	0.517***		-0.052	-0.050
		(0.735)	(0.519)		(0.001)	(0.002)		(0.596)	(0.613)
Share of registered four-wheelers		0.581	0.245		-2.650***	-2.677***		-1.418***	-1.422***
		(0.346)	(0.700)		(0.000)	(0.000)		(0.000)	(0.000)
Constant	-2.379*	-6.646*	-11.308***	-1.056	-2.708	-3.168	-5.938***	-1.734	-2.240
	(0.073)	(0.067)	(0.002)	(0.414)	(0.243)	(0.196)	(0.000)	(0.413)	(0.293)
Time dummies	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes
Income turning point (Rs)	—				—		12,353		
Observations	172	172	172	198	198	198	199	199	199
R-squared	0.516	0.589	0.640	0.471	0.727	0.733	0.316	0.341	0.374

Notes: P-values in parentheses, *** Significance at 1%, ** Significance at 5%, * Significance at 10%.
† Share of two-wheelers is the reference category.

Figure 5: Unconditionnal correlation between road traffic accident fatalities and income, 1994-2006

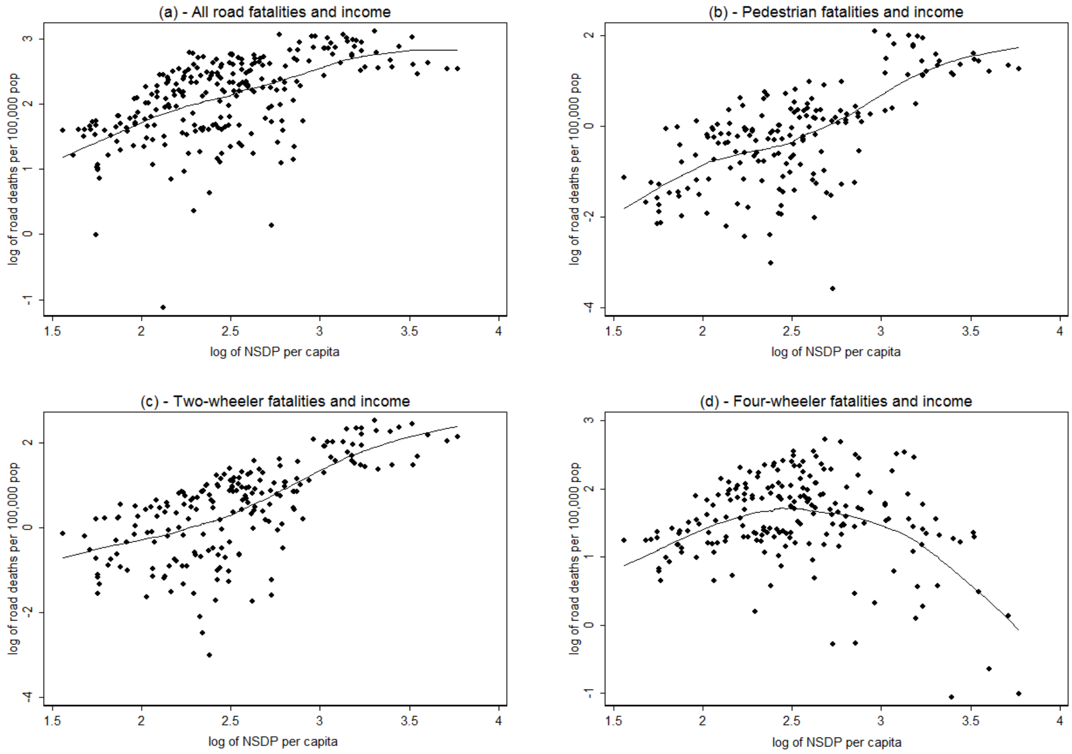


Table 5: Regressions of state fixed-effects on religious distribution (Hinduism is reference category)

Dependent variable fixed effects of:	All fatalities Table 3, col(6)	Pedestrian fatalities Table 4, col(3)	Two-wheeler fatalities Table 4, col(6)	Four-wheeler fatalities Table 4, col(9)
Islam (%)	1.797	28.303	15.145	4.746
	(0.479)	(0.187)	(0.108)	(0.421)
Sikhism (%)	-0.867	86.477	5.649	3.115
	(0.589)	(0.491)	(0.331)	(0.407)
Christianity (%)	-1.735*	-4.555	-5.872*	-2.201
	(0.052)	(0.500)	(0.064)	(0.264)
Buddhism, Jainism and other religions† (%)	-3.562*	-29.334	-30.794***	-13.752***
	(0.070)	(0.214)	(0.000)	(0.006)
Constant	-0.242	-2.820	-1.472	-0.013
	(0.558)	(0.439)	(0.325)	(0.989)
Observations	19	17	19	19
R-squared	0.471	0.384	0.764	0.578
Year used for regression	2004	2002	2004	2004
Joint significance of religion				
F-test	3.11	1.87	11.35	4.78
Prob>F	0.050	0.181	0.000	0.012

Notes: P-values in parentheses, *** Significance at 1%, ** Significance at 5%, * Significance at 10%.

Table 1A: Sources of data used

Variables	Source	Years covered	States covered
DEPENDENT VARIABLE			
Road traffic accident fatalities	NCRB	1994-2008	UT and statewise
Pedestrian, two-wheeler and four-wheeler road fatalities	NCRB	1996-2008	UT and statewise
INCOME			
Per capita net state domestic product at factor costs (constant prices, Rs)	Central Statistical Organisation	1994-2007	UT and statewise
SOCIO-DEMOGRAPHIC STRUCTURE			
Total population	Indian Censuses 1991 and 2001	1994-2008	UT and statewise
Percentage of male population	calculated based on Indian Censuses	1994-2008	UT and statewise
Percentage of urban population	calculated based on Indian Censuses	1994-2008	UT and statewise
Population density	calculated based on Indian Censuses	1994-2008	UT and statewise
Life expectancy	SRS, Registrar general of India	1994-2008	16 major states
Literacy rate	Indian Censuses	1994-2006	UT and statewise
Religious composition	calculated based on Indian Censuses	1994-2008	UT and statewise
ROAD AND HEALTH INFRASTRUCTURE			
Land size	NCRB	1994-2006	UT and statewise
Roads per km^2	calculated based on transportindia.in	1996-2004	statewise
Number of hospitals per 100,000 population	calculated based on CEHAT, Census 2001	1994-2003	UT and statewise
MOTORIZATION			
Registered motor vehicles by type	MORTH	1994-2006	UT and statewise
INSTITUTIONAL QUALITY			
Police expenditures per policeman (constant prices, Rs)	calculated based on NCRB	1994-2006	UT and statewise
Total cases for investigation per policeman	calculated based on NCRB	1994-2006	UT and statewise
Number of policemen per population	calculated based on NCRB	1994-2006	UT and statewise

Notes: NCRB: National Crime Records Bureau; MORTH: Ministry of Roads Transport and Highways; CEHAT: Centre for Enquiry into Health and Allied Themes.