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Traffic Fatalities and Economic Growth

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Abstract

Kopits and Cropper examine the impact of income growth on the death rate due to traffic fatalities, as well as on fatalities per motor vehicle and on the motorization rate (vehicles/population) using panel data from 1963–99 for 88 countries. Specifically, they estimate fixed effects models for fatalities/population, vehicles/population, and fatalities/vehicles and use these models to project traffic fatalities and the stock of motor vehicles to 2020.

The relationship between motor vehicle fatality rate and per capita income at first increases with per capita income, reaches a peak, and then declines. This is because at low income levels the rate of increase in motor vehicles outpaces the decline in fatalities per motor vehicle. At higher income levels, the reverse occurs. The income level at which per capita traffic fatalities peaks is approximately \$8,600 in 1985 international dollars. This is within the range of income at which other externalities, such as air and water pollution, have been found to peak.

Projections of future traffic fatalities suggest that the global road death toll will grow by approximately 66 percent between 2000 and 2020. This number, however, reflects divergent rates of change in different parts of the world—a decline in fatalities in high-income countries of approximately 28 percent versus an increase in fatalities of almost 92 percent in China and 147 percent in India. The authors also predict that the fatality rate will rise to approximately 2 per 10,000 persons in developing countries by 2020, while it will fall to less than 1 per 10,000 in high-income countries.

This paper—a product of Infrastructure and Environment, Development Research Group—is part of a larger effort in the group to study the externalities associated with motorization. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Viktor Soukhanov, room MC2-205, telephone 202-473-5721, fax 202-522-3230, email address vsoukhanov@worldbank.org. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at kopits@rff.org or mcropper@worldbank.org. April 2003. (42 pages)

TRAFFIC FATALITIES AND ECONOMIC GROWTH

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Traffic Fatalities and Economic Growth
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I. Introduction

As countries develop death rates usually fall, especially for diseases that affect the young and result in substantial life-years lost. Deaths due to traffic accidents are a notable exception: the growth in motor vehicles that accompanies economic growth usually brings an increase in road traffic accidents. Indeed, the World Health Organization has predicted that traffic fatalities will be the sixth leading cause of death worldwide and the second leading cause of disability-adjusted life-years lost in developing countries by the year 2020 (Murray and Lopez 1996). Table 1 highlights the increasing importance of the problem in several developing countries. For example, between 1975 and 1998, road traffic deaths per capita increased by 44% in Malaysia and by over 200% in Colombia and Botswana.

The situation in high-income countries is quite different. Over the same period, traffic fatalities per person decreased by 60% in Canada and Hong Kong, and by amounts ranging from 25% to 50% in most European countries. This reflects a downward trend in both the fatality rate (deaths/population) and in fatalities per kilometer traveled that began in most OECD countries in the early 1970's and has continued to the present.

Table 1. Change in Traffic Fatality Rate (Deaths/10,000 Persons), 1975-1998

Country	% Change ('75-'98)	Country	% Change ('75-'98)
Canada	-63.4%	Malaysia	44.3%
Hong Kong	-61.7%	India^	79.3%
Finland	-59.8%	Sri Lanka	84.5%
Austria	-59.1%	Lesotho	192.8%
Sweden	-58.3%	Colombia	237.1%
Israel	-49.7%	China	243.0%
Belgium	-43.8%	Botswana**	383.8%
France	-42.6%		
Italy*	-36.7%		
New Zealand	-33.2%		
Taiwan	-32.0%		
United States	-27.2%		
Japan	-24.5%		

*%change ('75-'97), **%change ('76-'98), ^%change ('80-'98).

These patterns are not surprising. The traffic fatality rate (fatalities/population) is the product of vehicles per person (V/P) and fatalities per vehicle (F/V). How rapidly fatality risk grows depends, by definition, on the rate of growth in motorization (V/P) and the rate of change in fatalities per vehicle (F/V).[1] In most developing countries over the past 25 years, vehicle ownership grew more rapidly than fatalities per vehicle fell. The experience in industrialized countries, however, was the opposite; vehicles per person grew more slowly than fatalities per vehicle fell. From these observations, two questions emerge: Why did these patterns occur? and What trends can be expected in the future?

To answer these questions we examine how the death rate (F/P) associated with traffic accidents and its components—V/P and F/V—change as countries grow. The topic is of interest for two reasons. For planning purposes it important to forecast the growth in traffic fatalities. Equations relating F/P to per capita income can be used to

[1]The fatality rate may also be expressed as the product of fatalities per vehicle kilometers traveled (F/VKT) and distance traveled per person (VKT/P). Lack of reliable time-series VKT data, especially. for developing countries, prevents us from using this measure for our analysis.

predict traffic fatalities by region. These forecasts should alert policymakers to what is likely to happen if measures are not enacted to reduce traffic accidents.

A second motive for our work comes from the literature on Environmental Kuznets Curves (Grossman and Krueger 1995). This literature examines the relationship between environmental externalities, such as air and water pollution, and economic growth. A focus of this literature has been in identifying the income levels at which externalities begin to decline. Road traffic fatalities are, indeed, an externality associated with motorization, especially in developing countries where pedestrians comprise a large share of casualties and motorists are often not insured. It is of interest to examine the income level at which the traffic fatality rate (F/P) historically has begun to decline and to compare this with the pattern observed for other externalities.

We investigate these issues by estimating equations for the motor vehicle fatality rate (F/P), the rate of motorization (V/P) and fatalities per vehicle (F/V) using panel data from 1963-99 for 88 countries. We estimate fixed effects models in which the natural logarithm of F/P, V/P and F/V are expressed as (a) a quadratic function of ln(Y) and (b) a spline function of ln(Y), where Y = real per capita GDP (measured in 1985 international prices). Time trends during the period 1963-99 are modeled in four ways: (1) a common linear time trend; (2) a common log-linear time trend; (3) regional, linear time trends; and (4) regional, log-linear time trends. These models are used to project traffic fatalities and the stock of motor vehicles to 2020.

Our main results are as follows. The per capita income at which the motor vehicle fatality rate begins to decline is in the range of incomes at which other externalities (specifically the common air pollutants) begin to decline—approximately

\$6100 (1985 international dollars) when a common time trend is assumed for all countries and \$8600 (1985 international dollars) when separate time trends are used for each geographic region. This turning point is driven by the rate of decline in F/V as income rises since V/P, while increasing with income at a decreasing rate, never declines with economic growth.

Projections of future traffic fatalities suggest that the global road death toll will grow by approximately 66% over the next twenty years. This number, however, reflects divergent rates of change in different parts of the world: a decline in fatalities in high-income countries of approximately 28% versus an increase in fatalities of almost 92% in China and 147% in India. We also predict that the fatality rate will rise to approximately 2 per 10,000 persons in developing countries by 2020, while it will fall to less than 1 per 10,000 in high-income countries.

The paper is organized at follows. Section II presents trends in fatality rates (F/P), motorization rates (V/P), and fatalities per vehicle (F/V) for various countries. Plots of each variable against per capita income motivate our econometric models. Section III describes the econometric models estimated and Section IV presents our projections of road traffic fatalities. Section V concludes.

II. How Fatality Risk, Motorization Rates and Fatalities/Vehicle Vary Across (and Within) Countries

Death rates (F/P) due to motor vehicle crashes are the product of the motorization rate (V/P) and fatalities per motor vehicle (F/V). Before estimating statistical models relating these ratios to per capita income it is useful to examine data showing how these quantities vary with income both within and across countries.

It is widely recognized that the motorization rate rises with income (Ingram and Liu (1999), Dargay and Gately (1999), Button et al. (1993)), implying that one should find large differences in vehicles per capita across countries at different stages of development and within countries as per capita incomes grow. Table 2 presents data on motorization rates for various countries in 1999.[2] Figure 1 plots the motorization rates for these countries against per capita income, pooling data from all countries and years, while Figure 2 shows how motorization rates have grown with income over time for a sample of countries.

Table 2. Motorization Rates, 1999, 60 Countries

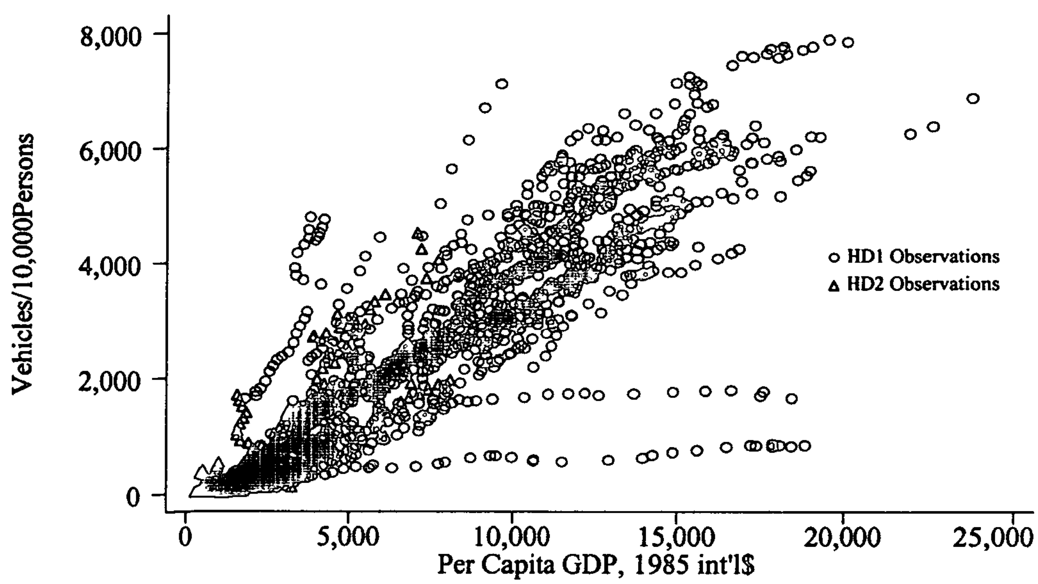
Country	Vehicles* /1,000 Persons	Country	Vehicles* /1,000 Persons
HD1 Countries:		*HD2 Countries:*	
United States	779	Malaysia	451
Luxembourg	685	Bulgaria	342
Japan[1]	677	Thailand[3]	280
Italy[2]	658	Latvia	267
Iceland	629	Mauritius	195
Switzerland	622	Romania	169
Australia[3]	616	South Africa	144
Austria	612	Panama[2]	112
Canada[1]	585	Turkey	100
Germany[1]	572	Indonesia[1]	81
New Zealand[2]	565	Sri Lanka[1]	74
Norway	559	Botswana	72
Cyprus	551	Swaziland[1]	69
Belgium	522	Colombia	67
Spain[2]	499	Benin[3]	52
Finland	498	Morocco	51
Sweden[1]	496	Ecuador[1]	47
Czechoslovakia	440	Philippines[1]	42

[2]The data in Table 2 and Figure 1 are displayed according to development status. Observations for countries with a UN Human Development Index (HDI) less than 0.8 are denoted as "HD2" and countries with an HDI value greater than 0.8 are labeled as "HD1".

United Kingdom[1]	434	Togo[3]	39
Netherlands	427	Mongolia	38
Denmark	424	Egypt[3]	35
Portugal[2]	423	India[2]	34
Bahrain	339	Nigeria[3]	29
Poland	323	Pakistan	23
Ireland3	312	Kenya[3]	14
Israel	301	Senegal[3]	14
Korea, Rep.	296	Bangladesh[2]	3.1
Hungary	283	Ethiopia[1]	1.5
Singapore	164		
Costa Rica	162		
Chile	138		
Hong Kong	80		

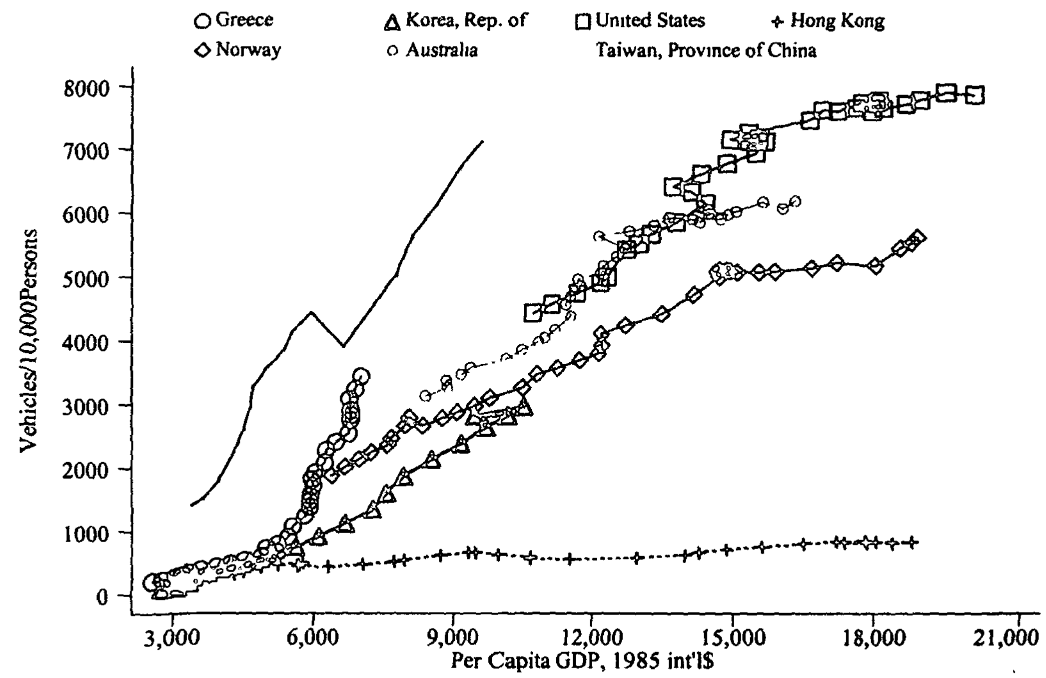
*Including passenger cars, buses, trucks, and motorized two-wheelers.
1- 1998 data, 2- 1997 data, 3- 1996 data.

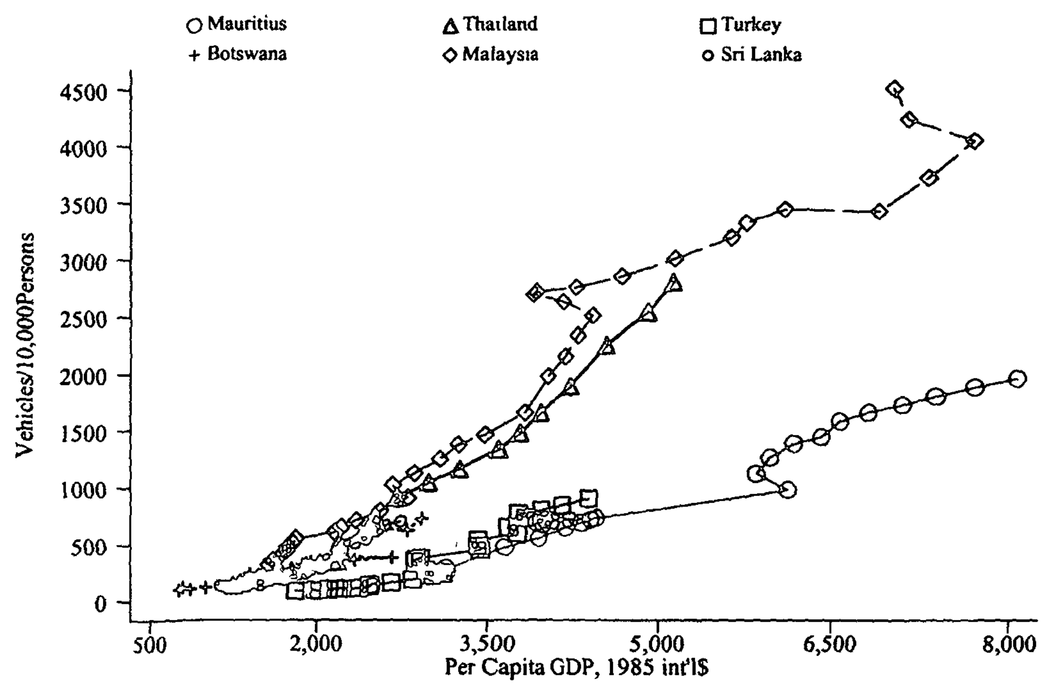
Figure 1. Motorization Rate vs. Income: All Countries and Years



The cross-sectional variation in motorization rates in Table 2 is striking. Vehicles per capita range from a high of 780 per 1,000 persons in the United States to fewer than 30 per 1,000 persons in countries such as Pakistan and Nigeria. High-income countries tend to have more vehicles per capita than lower income countries but there are important exceptions. Low motorization rates in Hong Kong, Singapore, Chile, and Costa Rica are notable outliers. Figure 1, which plots data on V/P for all countries and years in the dataset, suggests that, overall, motorization is strongly correlated with income. The within-group variation in motorization varies from country to country, however, as shown in Figure 2. Growth in vehicle ownership appears to have slowed down (but not declined) in many high-income countries such as Norway, Australia, Hong Kong, and the United States. In countries experiencing lower levels of per capita GDP such as Greece, Malaysia, and Thailand, however, vehicle fleets have continued to expand rapidly with income in recent decades.

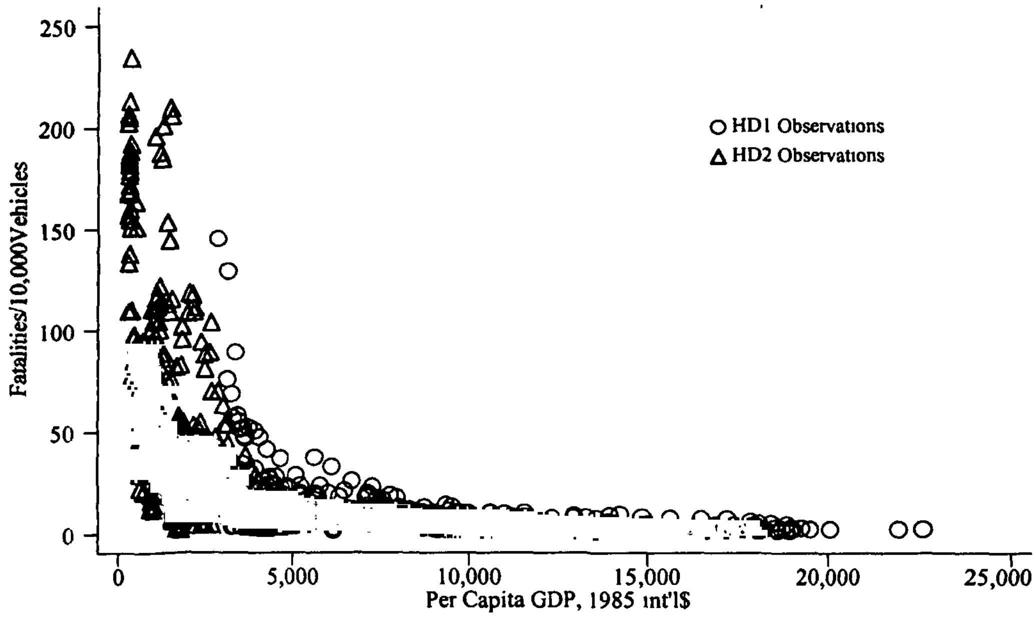
Figure 2. Motorization Rates vs. Income: Selected Countries





Fatalities per vehicle, by contrast, appear to decline steadily with income, at least after some low level of income, and then reach a floor. Both Figure 3, which plots the fatality rate (F/V) against income using data for all countries and years, and Figure 4, which shows how F/V has changed with income over time for a sample of countries, attest to this fact.[3] In part, the sharp decline in F/V with income reflects the fact that, as income rises, a higher percentage of travelers are vehicle passengers rather than pedestrians, and thus, are less likely to die in the event of a crash.[4] It also may reflect the move to safer vehicles (e.g., from two-wheelers to four-wheelers), safer roads, and/or changing attitudes toward risk as incomes grow.

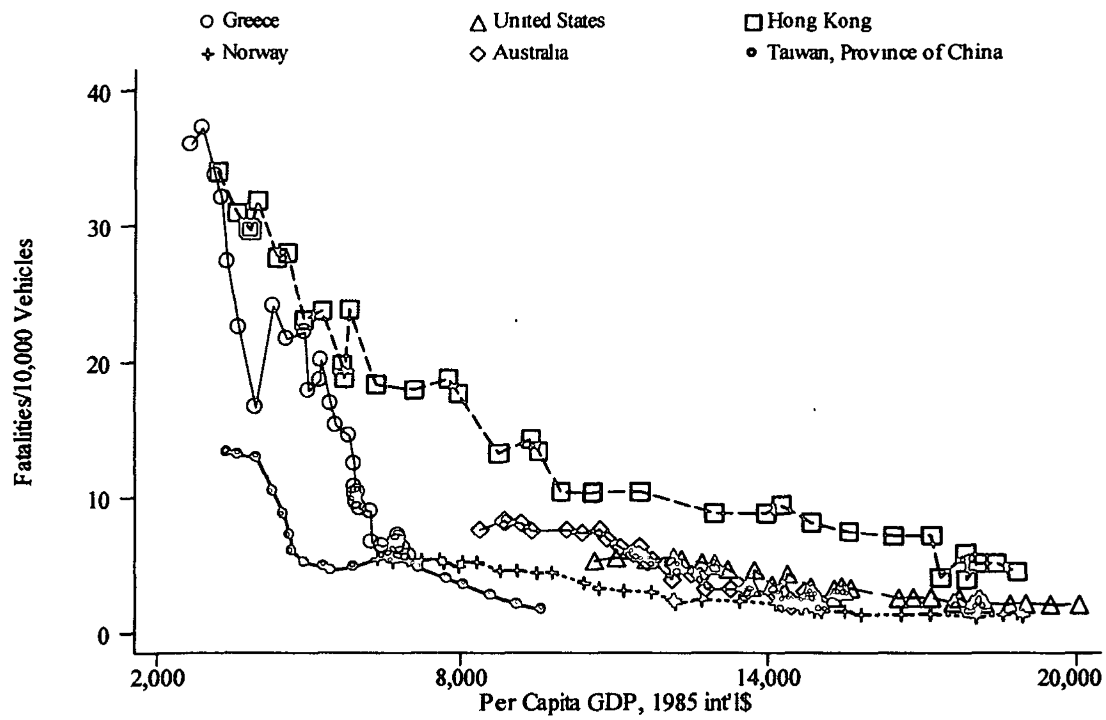
Figure 3. Fatalities/Vehicle vs. Income: All Countries and Years

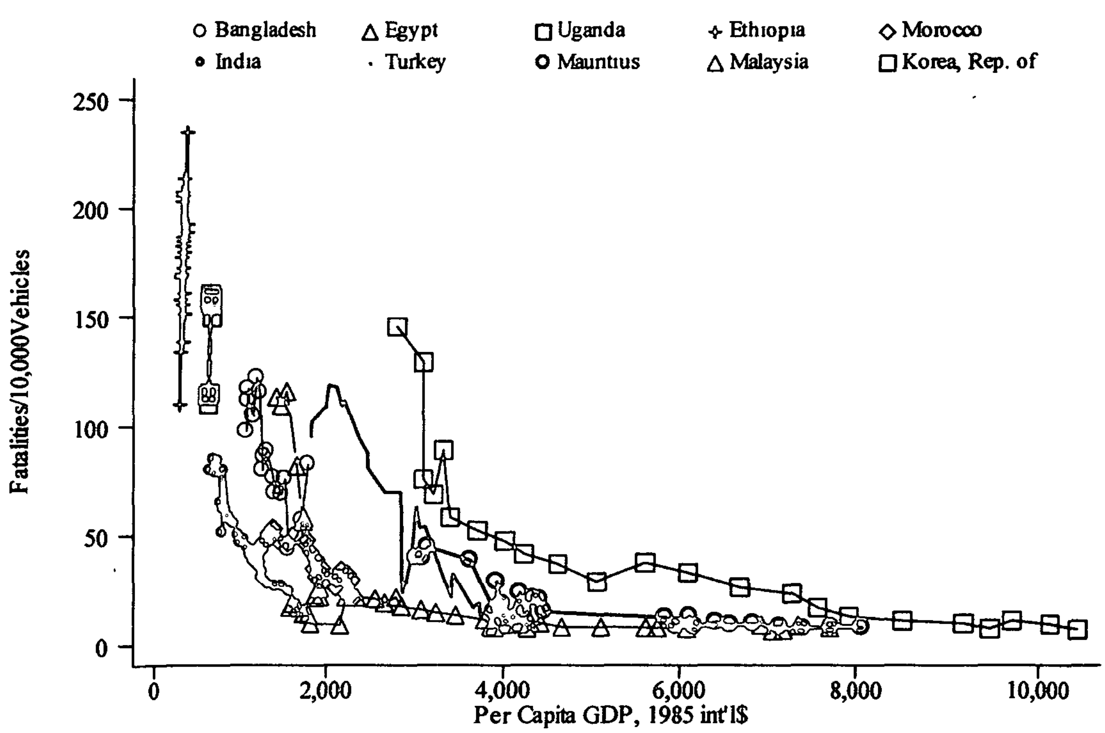


[3]The fatality figures used in Figures 3 and 4 have not been adjusted for underreporting of road deaths. Thus, F/V levels in developing countries may be underestimated.

[4] This point was first publicized by Smeed (1949), who demonstrated that F/V declines as V/P increases.

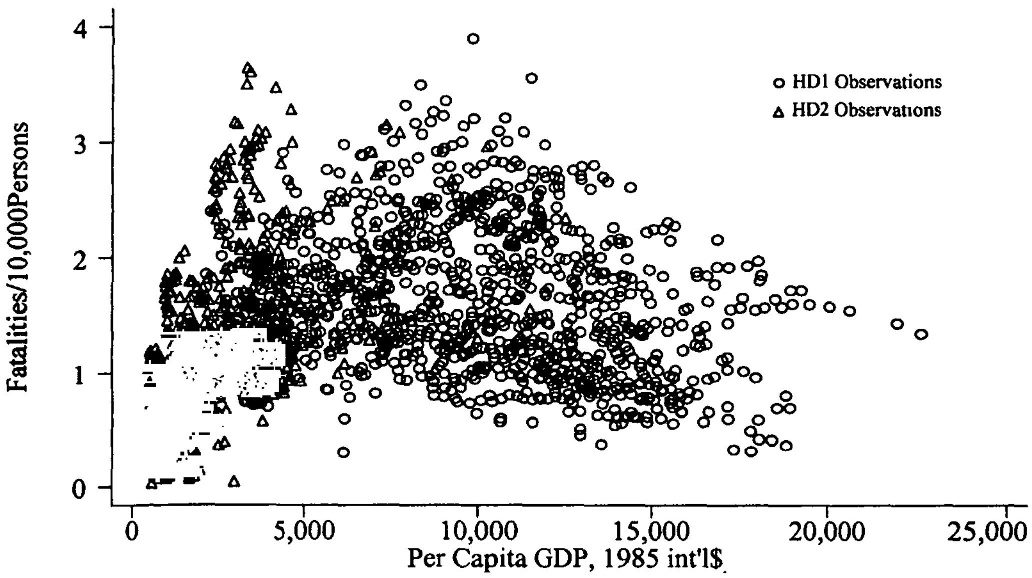
Figure 4. Fatalities/Vehicle v. Income: Selected Countries





The foregoing data suggest that one would expect to see the motor vehicle fatality rate (F/P) first increase and then decrease with income. Figure 5, which plots of F/P versus income for all years and countries in our dataset, supports this inverted U-shaped pattern. As incomes grow and vehicle fleets increase during initial stages of development, traffic fatality rates tend to worsen. At higher income levels, however, as growth in motorization slows and governments and individuals invest more in road safety, the decline in F/V drives the fatality rate (F/P) down.

Figure 5. Traffic Fatality Rate vs. Income: All Countries and Years



III. Statistical Models of Fatalities, Vehicle Ownership and Economic Growth

A. Models of Fatalities per Person

In fitting statistical models to the data on fatality risk we employ models of the general form:

(1) $\ln(F/P)_{it} = a_i + G(t) + F[\ln(Y_{it})] + \varepsilon_{it}$

where F/P = Fatalities/10,000 Persons, Y = Real Per Capita GDP (measured in 1985 international prices), a_i is a country-specific intercept, and G and F are functions. Two specific forms of F are used, a quadratic specification (equation (2)) and a spline (piecewise linear) specification (equation (3)):

(2) $\ln(F/P)_{it} = a_i + G(t) + b \ln Y_{it} + c (\ln Y_{it})^2 + \varepsilon_{it}$

(3) $\ln(F/P)_{it} = a_i + G(t) + b \ln Y_{it} + \Sigma_s [c_s D_s(\ln Y_{it} - \ln Y_s)] + \varepsilon_{it}$

where D_s is a dummy variable = 1 if Y_{it} is in income category s+1, and Y_s is the cutoff income value between the s and s+1 income group. Following Schmalensee et al. (2000), we divide the observations into 10 income groups with an equal number of observations in each spline segment.

Four different forms of $G(t)$ are used: (1) a common linear time trend; (2) a common log-linear time trend (ln t); (3) regional, linear time trends; and (4) regional, log-linear (ln t) time trends. For purposes of defining time trends, we divide countries into two groups: highly developed countries (HD1)—i.e., countries that have a Human Development Index in 1999 of 0.8 or greater—and all other countries (HD2).[5] In practice, this division of countries (shown in detail in the Appendix) corresponds closely

[5] The United Nations Human Development Index measures per capita income, life expectancy and educational achievement.

to highly-motorized countries versus other countries. All HD1 countries are treated as a single region for the purposes of computing time trends. HD2 countries, in turn, are classified according to region. Table 3 shows the number of countries in each geographic region, for both HD1 and HD2 countries.

Table 3. Regional Distribution of Countries Used in Model Estimation

WB Region	HD2	HD1
East Asia & Pacific	10	1
E. Europe & Central Asia	5	3
Latin America & Caribbean	5	2
Middle East & North Africa	8	1
South Asia	5	
Sub-Saharan Africa	20	
High-Income Countries		28
Total:	53	35

The inclusion of country-specific intercepts in equation (1) implies that the impact of income on the fatality rate will reflect within- rather than between-country variation in ln(F/P) and ln(Y). This is desirable for two reasons. For the purposes of predicting future trends in F/P it is more desirable to rely on within-country experience rather than on largely cross-sectional variation in income and fatality risk. Using only cross-country variation to predict the future pattern of traffic fatalities is equivalent to saying that once Indonesia reaches the income level of Greece, its road safety record will mirror that of Greece. The second reason is that countries differ in their definition of what constitutes a traffic death and in the percentage of deaths that are reported. (This topic is discussed more fully in Section IV.) To the extent that the degree of under-reporting remains constant over time but varies across countries it will not affect estimates of the impact of economic growth on fatality risk.[6]

Equations (2) and (3) are estimated using panel data for 88 countries for the period 1963-99. To be included in the dataset a country must have at least 10 years of data on traffic fatalities. Table A.1 in the Appendix lists the countries used to estimate the models and the number of years of data that are available for each country. The data on traffic fatalities used in this study come primarily from the International Road Federation Yearbooks, which have been supplemented by and cross-checked against various other sources. The sources of traffic fatality and all other data are described in the Appendix.

B. Empirical Results

Table 4 summarizes the results of estimating the 8 models formed by combining the quadratic and spline functions with 4 methods of treating time trends. (Complete regression results are displayed in Table A.2. in the Appendix.) The table shows the income level at which F/P first begins to decline as well as the time coefficients for each model. To give a more complete picture of the model results, Figures 6 and 7 plot F/P as a function of per capita income.[7] Figure 6 shows the quadratic and spline models with a common linear time trend while Figure 7 plots the quadratic and spline models with region-specific log-linear time trends.

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[6] To illustrate, when equation (2) is estimated using country-specific intercepts, the coefficients b and c reflect within-country variation in fatalities and income. Multiplying country i's fatality rate by a constant to reflect under-reporting would not change the estimates of b and c.

[7] In both figures, F/P results are displayed using the country intercept for India with the time trend set equal to 1999.

Table 4. Regression Results from Fatalities/Population Models

	Quadratic				Spline			
	1	2	3	4	5	6	7	8
Turning Point (1985$int'l)	$5,385	$4,825	$10,784	$5,738	$6,095	$6,095	$8,592	$8,592
95% C.I.:	[$4977, $5826]	[$4489, $5186]	[$8644, $13455]	[$5141, $6403]				
<u>*Common time trend, t:*</u>	-0.0010 *(0.0010)*	0.0346* *(0.0123)*			0.0013 *(0.0010)*	0.0555* *(0.0122)*		
<u>*Regional ts:*</u>								
EAP			0.0054 *(0.0029)*	0.2377* *(0.0417)*			0.0065* *(0.0029)*	0.2573* *(0.0416)*
ECA			-0.0100* *(0.0032)*	0.0162 *(0.0399)*			-.0126* *(0.0032)*	-0.0305 *(0.0403)*
India			0.0194* *(0.0048)*	0.2789* *(0.0591)*			0.0225* *(0.0048)*	0.3189* *(0.0579)*
LAC			0.0145* *(0.0032)*	0.3100* *(0.0625)*			0.0120* *(0.0032)*	0.2639* *(0.0615)*
MNA			-0.0093* *(0.0023)*	-0.0301 *(0.0301)*			-.0067* *(0.0025)*	0.0106 *(0.0324)*
SA			-0.0015 *(0.0031)*	0.0361 *(0.0389)*			0.0041 *(0.0032)*	0.0956* *(0.0388)*
SSA			0.0101* *(0.0013)*	0.1468* *(0.0191)*			0.0106* *(0.0013)*	0.1609* *(0.0186)*
High Income			-0.0191* *(0.0016)*	-.0783* *(0.0177)*			-.0154* *(0.0017)*	-.0567* *(0.0176)*

*Significant at the 95% confidence level.
Standard Errors are given in parentheses.

8 Model Specifications:
1. Quadratic, common linear time trend
2. Quadratic, common log-linear time trend
3. Quadratic, regional linear time trends
4. Quadratic, regional, log-linear time trends
5. Spline, common linear time trend
6. Spline, common log-linear time trend
7. Spline, regional linear time trends
8. Spline, regional, log-linear time trends

Several results are worth emphasizing. The income levels at which the fatality rate first declines are higher when region-specific time trends are included in the models rather than a common time trend. For example, F/P begins to decline at approximately $8600 in the spline models with region-specific time trends but at approximately $6100 in the spline models with a common time trend. This reflects the fact that, in many developing countries, fatality risk over the period 1963-99 grew faster than could be explained by income growth alone. Because the region-specific time trends are jointly significant, we believe that more emphasis should be placed on these models than on models with a common time trend.

Whether the time trend enters the models linearly or in log-linear form, the differences in trends across regions are generally similar. Over the estimation period (1963-99) the fatality rate grew fastest in India and in Latin America (LAC) (holding income constant), and almost as fast in Sub-Saharan Africa as in LAC. By contrast, (holding income constant) F/P declined in high-income countries. Results for other regions are statistically insignificant in at least some specifications.

Figure 6. Fatalities/Population Results, Common Linear Time Trend

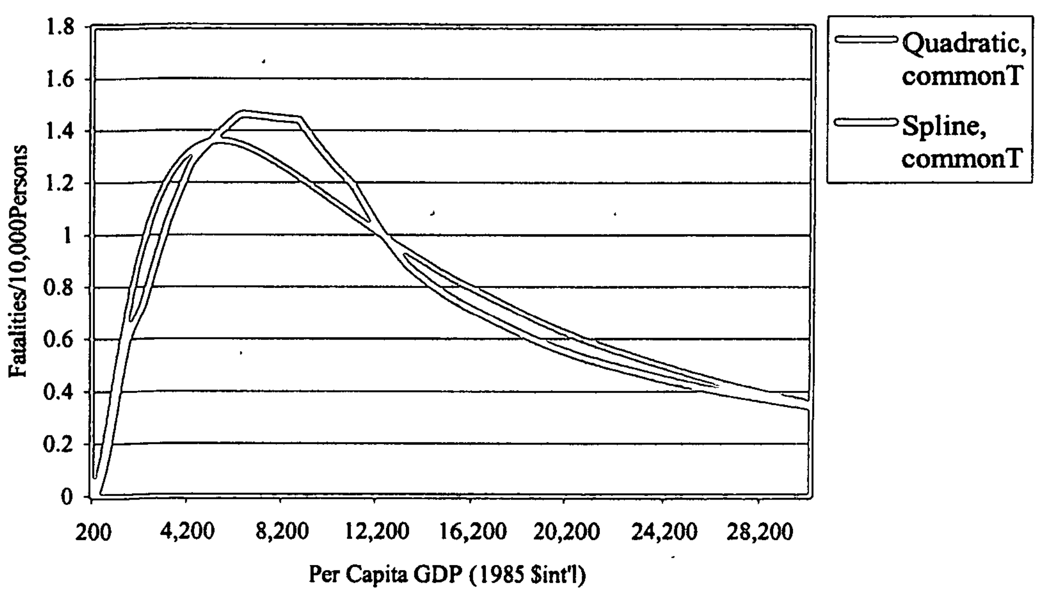
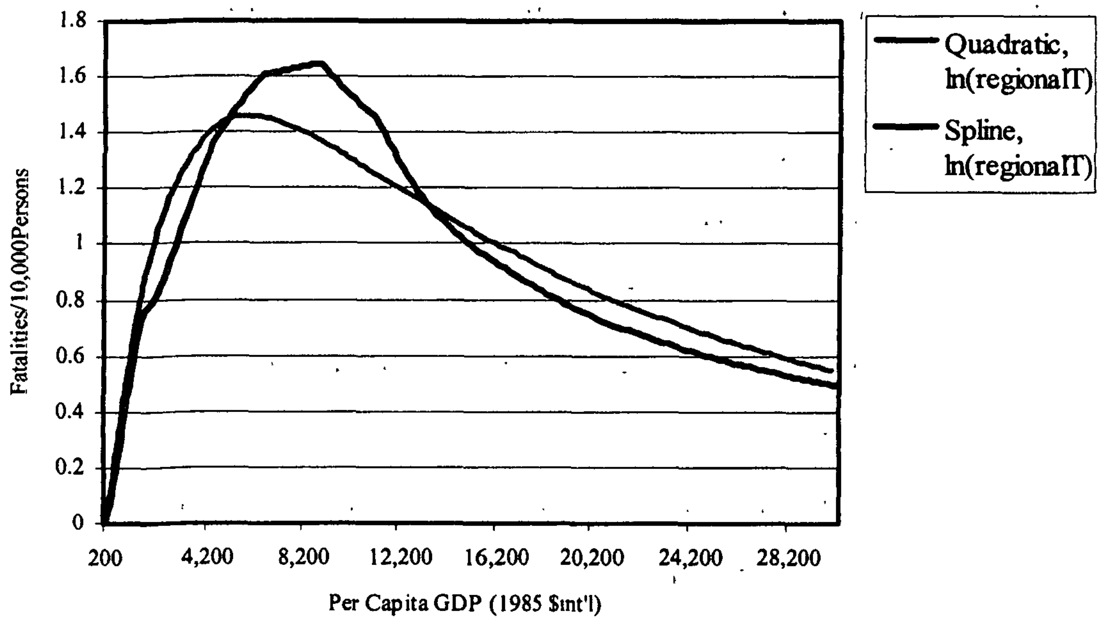


Figure 7. Fatalities/Population Results, Log-Linear Regional Time Trends



It is also clear from examining Figures 6 and 7 that the relationship between per capita income and the fatality rate is quite similar (holding the treatment of time constant) whether one uses the quadratic or spline function. When a common time trend is assumed F/P begins to decline at an income of $5,400 using the quadratic specification and at an income of $6,100 with the spline model. When region-specific, log-linear time trends are included F/P begins to decline at an income of $5,700 in the quadratic model and at an income of $8,600 in the spline model. In both figures, the two models are almost identical at low levels of income; however, the fatality rate peaks at a higher level of income in the spline model and falls faster than in the quadratic model after it peaks.

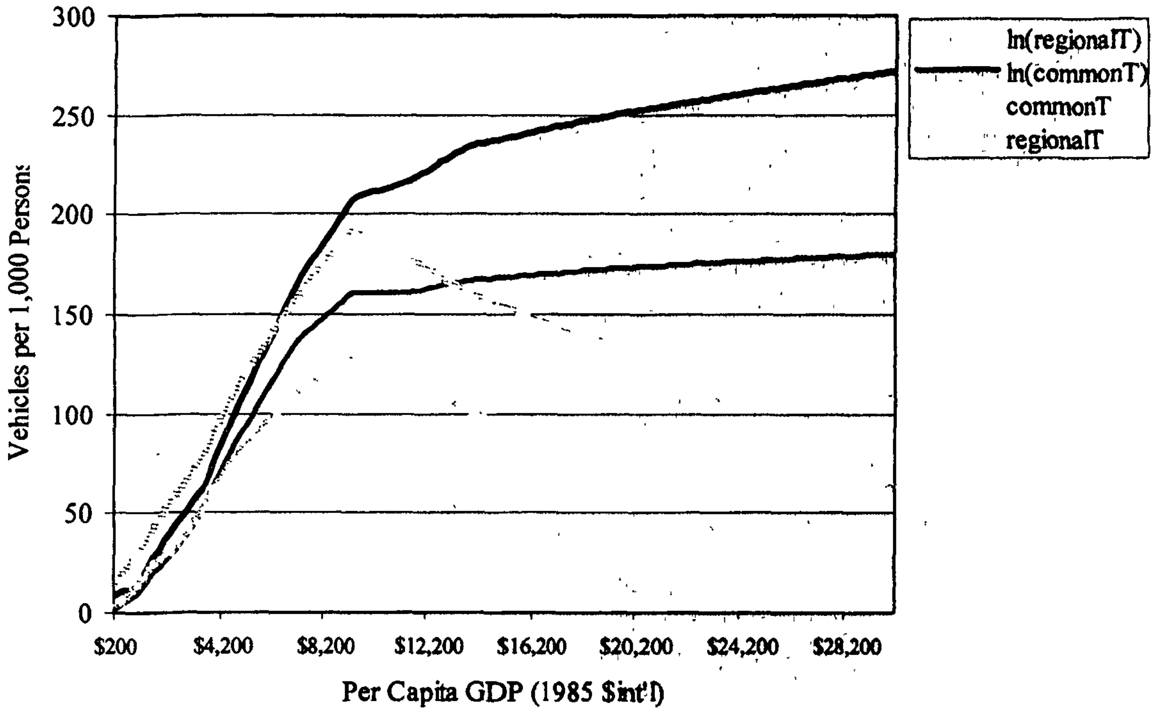
In the Kuznets Curve literature it is standard practice to focus on the income level at which the externality in question begins to decline. The usual interpretation is that, if a country follows historical trends, the problem in question will eventually lessen once per capita income reaches this turning point. Because the spline is a more flexible functional form, we focus on the spline results in Table 4. The income levels at which fatalities per person peak in the spline models, \$6100 and \$8600 (1985 international dollars) are within the range of incomes at which Kuznets curves for common air and water pollutants peak (Grossman and Krueger 1995). To better understand why this occurs, in the next sections we examine models similar to those in Table 4 for the two components of fatalities per person—vehicles per person and fatalities per vehicle.

C. Models of Vehicles per Person

Models for vehicles per person (V/P) are summarized in Table 5 and Figure 8. Table 5 shows how motorization (V/P) varies with income in the both the quadratic and spline models. Our discussion, however, focuses on the spline models. Figure 8 plots the four spline models using the country intercept for India, with the time trend set equal to 1999.

Of the four spline models in Table 5, only two (Models 6 and 8) show vehicles per person increasing with per capita income at a decreasing rate for all relevant values of per capita income. This result occurs when time is entered in a log-linear fashion; when it enters the motorization equation linearly, V/P peaks at a value of income observed in the data, and the time trend associated with vehicle ownership is large and positive. The log-linear time trend thus seems to yield more reasonable results than the linear. Of the two models with log-linear time trends, only the model with regional log-linear time trends yields non-negative income elasticities for all levels of income; hence we focus on this model.

Figure 8. Vehicles/Population Results, Spline Models



Notes for Table 5:

Standard Errors are given in parentheses.
The constant term reflects the intercept term for India. Country fixed effects were included in all regressions but are not displayed here.
Asterisks indicate significance at the 95% confidence level.

Model Specifications:

1. Quadratic, common linear time trend
2. Quadratic, common log-linear time trend
3. Quadratic, regional linear time trends
4. Quadratic, regional, log-linear time trends
5. Spline, common linear time trend
6. Spline, common log-linear time trend
7. Spline, regional linear time trends
8. Spline, regional, log-linear time trends

Table 5. Regression Results from Vehicles/Population Models

Independent Variables	Quadratic				Spline			
	1	2	3	4	5	6	7	8
LnY	5.5228*	5.0464*	3.0785*	3.0826*				
	(0.2120)	*(0.2301)*	*(0.2976)*	*(0.3042)*				
$(\ln Y_{it})^2$	-0.2860*	-0.2407*	-0.1420*	-0.1242*				
	(0.0129)	*(0.0138)*	*(0.0182)*	*(0.0183)*				
<u>lnY for:</u>								
\$1 - \$946					0.8569*	0.9551*	0.4247*	0.1899
					(0.1281)	*(0.1473)*	*(0.1239)*	*(0.1471)*
\$946 - \$1,535					1.4314*	1.7748*	0.9087*	1.6752*
					(0.1020)	*(0.1149)*	*(0.1088)*	*(0.1168)*
\$1,535 - \$2,290					0.6748*	1.0435*	0.7078*	1.0849*
					(0.1027)	*(0.1157)*	*(0.1139)*	*(0.1258)*
\$2,290 - \$3,441					1.3786*	1.5083*	0.8825*	1.0385*
					(0.1115)	*(0.1285)*	*(0.1127)*	*(0.1332)*
\$3,441 - \$4,682					1.2179*	1.5702*	1.1359*	1.5656*
					(0.1347)	*(0.1524)*	*(0.1250)*	*(0.1426)*
\$4,682 - \$6,911					0.8052*	1.1438*	0.8378*	1.1870*
					(0.1025)	*(0.1156)*	*(0.0955)*	*(0.1081)*
\$6,911 - \$9,238					0.5691*	0.5949*	0.6883*	0.8223*
					(0.1267)	*(0.1462)*	*(0.1193)*	*(0.1399)*
\$9,238-\$11,263					-0.4359*	-0.0216	-0.3367*	0.1884
					(0.1756)	*(0.1999)*	*(0.1663)*	*(0.1902)*
\$11,263-13,663					-0.7142*	0.2125	-0.5504*	0.4123*
					(0.1750)	*(0.1941)*	*(0.1693)*	*(0.1835)*
> \$13,663					-0.6119*	0.0978	-0.5092*	0.1897
					(0.1477)	*(0.1650)*	*(0.1396)*	*(0.1540)*
Turning Point (1985\$int'l)	\$15,587	\$35,723	\$51,179	\$244117	\$9,238	-	\$9,238	-
95% C.I.:	[\$12995, \$18,696]	[\$26690, \$47,813]	[\$24,687, \$106099]	[\$71,420, \$834411]				
<u>Common time trend</u>: t	0.0281*	0.2358*			0.0322*	0.2631*		
	(0.0010)	*(0.0132)*			*(0.0010)*	*(0.0130)*		
<u>Regional t:</u>								
EAP			0.0539*	0.5587*			0.0582*	0.5990*
			(0.0027)	*(0.0417)*			*(0.0026)*	*(0.0418)*
ECA			0.0597*	0.5400*			0.0559*	0.5046*
			(0.0031)	*(0.0389)*			*(0.0030)*	*(0.0400)*
India			0.0657*	0.6619*			0.0747*	0.7331*
			(0.0039)	*(0.0501)*			*(0.0037)*	*(0.0483)*
LAC			0.0256*	0.2184*			0.0234*	0.2017*
			(0.0042)	*(0.0574)*			*(0.0040)*	*(0.0572)*
MNA			0.0157*	0.0449*			0.0201*	0.0358
			(0.0029)	*(0.0368)*			*(0.0030)*	*(0.0385)*
SA			0.0359*	0.2547*			0.0406*	0.2468*
			(0.0027)	*(0.0365)*			*(0.0027)*	*(0.0361)*
SSA			0.0290*	0.3119*			0.0304*	0.3529*
			(0.0014)	*(0.0202)*			*(0.0013)*	*(0.0196)*
High Income			0.0215*	0.1604*			0.0292*	0.1977*
			(0.0014)	*(0.0168)*			*(0.0014)*	*(0.0168)*
F statistic on regional ts:			$F_{8,1791}$ = 151.15	$F_{8,1791}$ = 80.03			$F_{8,1783}$ = 202.95	$F_{8,1783}$ = 96.64
Constant	-20.688*	-19.675*	-11.378*	-12.806*	-2.2872*	-3.1038*	-0.0692	0.8421
	(0.8645)	*(0.9430)*	*(1.1795)*	*(1.2143)*	*(0.8586)*	*(0.9835)*	*(0.8261)*	*(0.9753)*
Adjusted R2:	0.9783	0.9742	0.9818	0.9775	0.9820	0.9767	0.9849	0.9799
No. of Countries: 75, No. of observations: 1876								

In the preferred model, Model 8, the income elasticity of vehicle ownership attains a maximum value of 1.67 in the second spline segment ($946 - $1,535 (1985 international dollars)) and decreases to a low of 0.18 in the highest income category. Above the lowest income category, income elasticities in income categories 2 through 5 are significantly higher than income elasticities in income categories 7 to 10.[8] These results are broadly consistent with previous studies of motorization, which find that the income elasticity of demand for motor vehicles declines with income (Ingram and Liu (1998), Dargay and Gately (1999), Button et al. (1993)). Figure 8 suggests that the rate of increase in motorization slows down considerably after reaching a per capita income of $9400 (1985 international dollars), the level of income attained by Norway and the United Kingdom in 1974.

D. Models for Fatalities per Vehicle

Table 6 and Figure 9 confirm that fatalities per vehicle decline sharply with income. Focusing once again on the spline models with log-linear time trends, F/V declines with income for per capita GDP in excess of $1,180 (1985 international dollars) when either common or regional log-linear time trends are used. Figure 9, which plots the four spline models for India (t = 1999) indicates exactly how fast F/V declines as income grows. Fatalities per vehicle decline by a factor of 3 (e.g., from 360 to 120 per 100,000 vehicles for India) as per capita income grows from $1200 to $4400. After reaching a per capita income of $15,200 (1985 international dollars), however, F/V

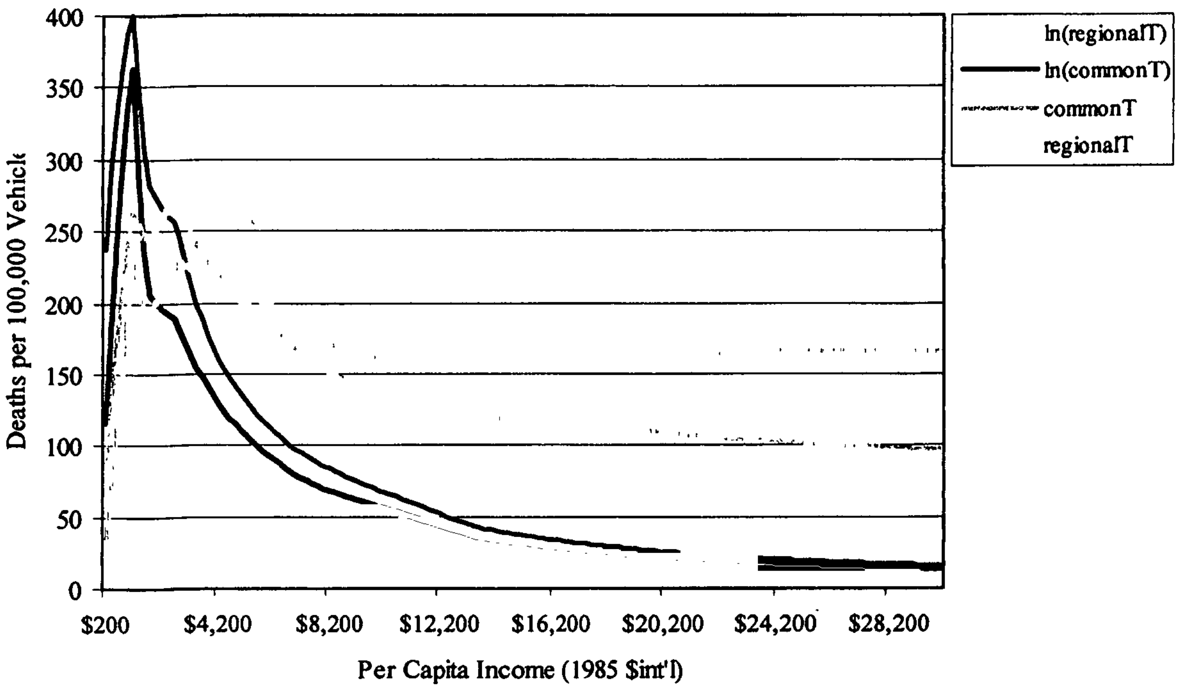
[8] Income elasticity estimates generated from a two-segment spline model are statistically different from each other, decreasing from 1.32 *(0.051)* to 0.719 *(0.052)* once per capita income exceeds $4,682 (1985 international dollars).

Table 6. Regression Results from Fatalities/Vehicles Models

Independent Variables	Quadratic				Spline			
	1	2	3	4	5	6	7	8
LnY	2.3796*	3.0043*	2.2926*	3.0550*				
	(0.2509)	*(0.2915)*	*(0.3829)*	*(0.4240)*				
$(\ln Y_{it})^2$	-0.1612*	-0.2313*	-0.1458*	-0.2340*				
	(0.0151)	*(0.0173)*	*(0.0231)*	*(0.0252)*				
lnY for:								
$1-$1,179					0.6190*	0.3024*	1.0517*	0.6548*
					(0.1167)	*(0.1372)*	*(0.1268)*	*(0.1551)*
$1,179-$1,730					-0.2292	-0.9258*	-0.5022*	-1.5227*
					(0.1468)	*(0.1697)*	*(0.1585)*	*(0.1867)*
$1,730-$2,698					0.2538	-0.2607	0.4462*	-0.2433
					(0.1334)	*(0.1552)*	*(0.1426)*	*(0.1711)*
$2,698-$3,813					-0.5814*	-1.0952*	-0.0908	-0.8321*
					(0.1485)	*(0.1751)*	*(0.1519)*	*(0.1834)*
$3,813-$5,391					-0.3880*	-0.9340*	-0.1747	-0.8727*
					(0.1415)	*(0.1640)*	*(0.1359)*	*(0.1620)*
$5,391-$7,532					-0.5550*	-1.0029*	-0.4913*	-1.0357*
					(0.1447)	*(0.1686)*	*(0.1391)*	*(0.1668)*
$7,532-$9,614					-0.6347*	-0.9444*	-0.3684*	-0.8750*
					(0.1745)	*(0.2075)*	*(0.1697)*	*(0.2083)*
$9,614-$11,469					-0.2826	-1.1976*	0.0859	-1.1407*
					(0.2421)	*(0.2824)*	*(0.2354)*	*(0.2810)*
$11,469-13,682					-0.4438	-1.8455*	0.0051	-1.7977*
					(0.2363)	*(0.2690)*	*(0.2333)*	*(0.2664)*
>$13,682					-0.2782	-1.2485*	0.0143	-1.2226*
					(0.1905)	*(0.2185)*	*(0.1855)*	*(0.2151)*
Turning Point (1985$int'l)	$1,603	$661	$2,593	$683	$2,698	$1,179	$2,698	$1,179
95% C.I.:	[$1,189, $2,161]	[$475, $920]	[$1,859, $3,616]	[$440, $1,061]				
Common time trend: t	-0.0370*	-0.2335*			-0.0386*	-0.2285*		
	(0.0013)	*(0.0170)*			*(0.0013)*	*(0.0176)*		
Regional t:								
EAP			-0.0512*	-0.2661*			-0.0561*	-0.2826*
			(0.0034)	*(0.0540)*			*(0.0034)*	*(0.0560)*
ECA			-0.0671*	-0.4416*			-0.0698*	-0.4609*
			(0.0036)	*(0.0487)*			*(0.0038)*	*(0.0522)*
India			-0.0445*	-0.3551*			-0.0536*	-0.4416*
			(0.0049)	*(0.0686)*			*(0.0050)*	*(0.0701)*
LAC			-0.0123*	-0.0219			-0.0127*	-0.0142
			(0.0060)	*(0.1362)*			*(0.0061)*	*(0.1387)*
MNA			-0.0268*	-0.0503			-0.0234*	0.0922
			(0.0035)	*(0.0490)*			*(0.0039)*	*(0.0543)*
SA			-0.0392*	-0.1925*			-0.0375*	-0.1230*
			(0.0033)	*(0.0462)*			*(0.0035)*	*(0.0473)*
SSA			-0.0289*	-0.2527*			-0.0284*	-0.2365*
			(0.0020)	*(0.0311)*			*(0.0019)*	*(0.0306)*
High Income			-0.0424*	-0.2293*			-0.0470*	-0.2450*
			(0.0017)	*(0.0215)*			*(0.0018)*	*(0.0223)*
F statistic on regional ts:			$F_{8,1615}$ = 132.45	$F_{8,1615}$ = 29.78			$F_{8,1607}$ = 140.67	$F_{8,1607}$ = 31.56
Constant	-11.105*	-12.166*	-11.092*	-12.055*	-6.5829*	-4.5175*	-9.2431*	-6.3274*
	(1.0305)	*(1.2035)*	*(1.5275)*	*(1.7003)*	*(0.7967)*	*(0.9333)*	*(0.8365)*	*(1.0105)*
Adjusted R2:	0.9532	0.9363	0.9569	0.9377	0.9540	0.9368	0.9588	0.9394
No. of Countries: 70, No. of observations: 1695								

declines very slowly in absolute terms: from 25 per 100,000 vehicles at an income of $20,000 to 15 per 100,000 vehicles at an income of $30,000.

Figure 9. Fatalities/Vehicle Results, Spline Models



Combining the results of model 8 for F/V and for V/P explains the results for deaths per capita observed in Figure 7. The elasticity of V/P with respect to income exceeds in absolute value the elasticity of F/V with respect to income for incomes up to the $7,000-$9,000 interval, when the two elasticities are approximately equal—the condition for (F/V)*(V/P) to peak.[9] At higher incomes, the elasticity of fatalities per vehicle with respect to income exceeds the elasticity of motorization with respect to income.

[9] This comparison is approximate since the width of the income intervals differs in Tables 5 and 6.

IV. Predictions of Future Traffic Fatalities and Motorization

One reason for estimating the preceding models is to predict what will happen to traffic fatalities if historic trends continue. Future traffic fatalities can be predicted directly from equation (1); i.e., by predicting future fatality rates (F/P) and multiplying by estimates of future population, or by predicting vehicle ownership, V, from the V/P equation and multiplying the vehicle stock by fatalities per vehicle. The second method serves as a check on the first since more is known about vehicle ownership. In particular, one can reject models that yield unbelievably high rates of vehicle ownership; e.g., ownership significantly in excess of one vehicle per person in the year 2020.

To project future vehicle ownership and traffic fatalities assumptions must be made about income and population growth. The real per capita GDP series is projected to 2020 using the World Bank's forecasts of regional growth rates (2000-2010) (Global Economic Prospects 2002) with the assumption that the average annual 2001-2010 growth rates continue to 2020. (A list of the growth rates is provided in Appendix Table A.3.) Population projections are taken from the U.S. Census International Data Base. In total, the explanatory variables are available for 156 countries (representing 92% of total world population in 2000), including 45 highly developed countries (HD1) and 111 developing countries (HD2). Table 7 shows the number of countries in each geographic region for which predictions are made.

Table 7. Regional Distribution of Countries for Which Predictions are Made

WB Region	HD2	HD1
East Asia & Pacific	14	1
E. Europe & Central Asia	5	4
Latin America & Caribbean	27	4
Middle East & North Africa	12	1
South Asia	7	
Sub-Saharan Africa	46	
High-Income Countries		35
Total:	111	45

To calculate the point estimates for the out-of-sample countries, assumptions must be made regarding the country-specific intercept. The coefficient on the country dummy variable for Chile is used to compute the predicted values for the 10 out-of-sample HD1 countries.[10] For the HD2 countries, the intercept is set equal to the mean of the country intercepts for the corresponding region.

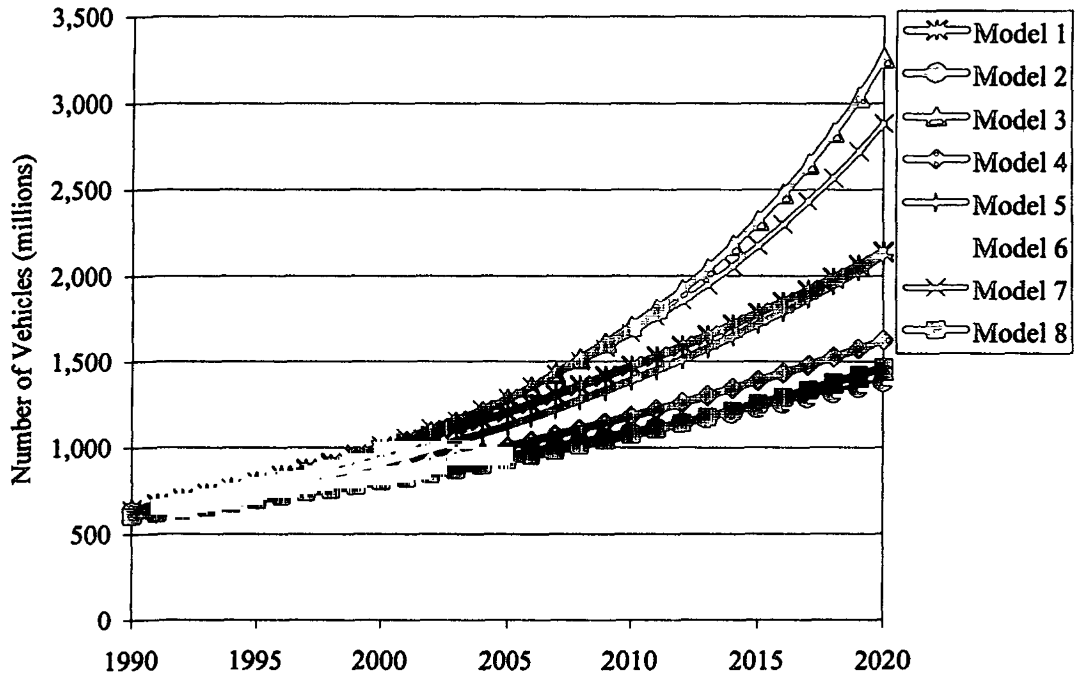
A. Projections of the World Vehicle Fleet to 2020

We begin by examining the implications of the models in Table 5 for future growth in vehicle ownership. Figure 10 displays projections of the vehicle fleet corresponding to all 8 models in Table 5. Not surprisingly, it is the form of the time trend, rather than the choice between the spline and quadratic specifications, that makes the greatest difference in the projections. Both the spline and quadratic models with linear regional time trends yield unbelievably large estimates of the world motor vehicle stock in 2020, as well as estimates of vehicle ownership per capita for certain groups of countries that are well over 1. For this reason we focus on the spline models with log-

[10] The choice of Chile is motivated by the fact that the most populous out-of-sample HD1 countries for which predictions must be made are Argentina and Uruguay.

linear time trends. The model with region-specific log-linear time trends (Model 8) generates forecasts of 1.47 billion vehicles in 2020, whereas the vehicle stock is predicted to be over 1.37 billion vehicles when a common log-linear time trend is used (Model 6).[11]

Figure 10. World Vehicle Fleet Projections Corresponding to Models in Table 5



The predictions of these models agree fairly well with other estimates of vehicle growth in the literature. Dargay and Gately (1999) project that the total vehicle fleet in OECD countries will reach 705 million by 2015 (a 62% increase from 1992 values). The spline model (with the common time trend or the log-linear regional time trends) yields a 2015 estimate of 687 million vehicles for the same group of countries.

[11] The corresponding quadratic models give almost identical vehicle projections but we continue to focus on the more flexible spline specifications.

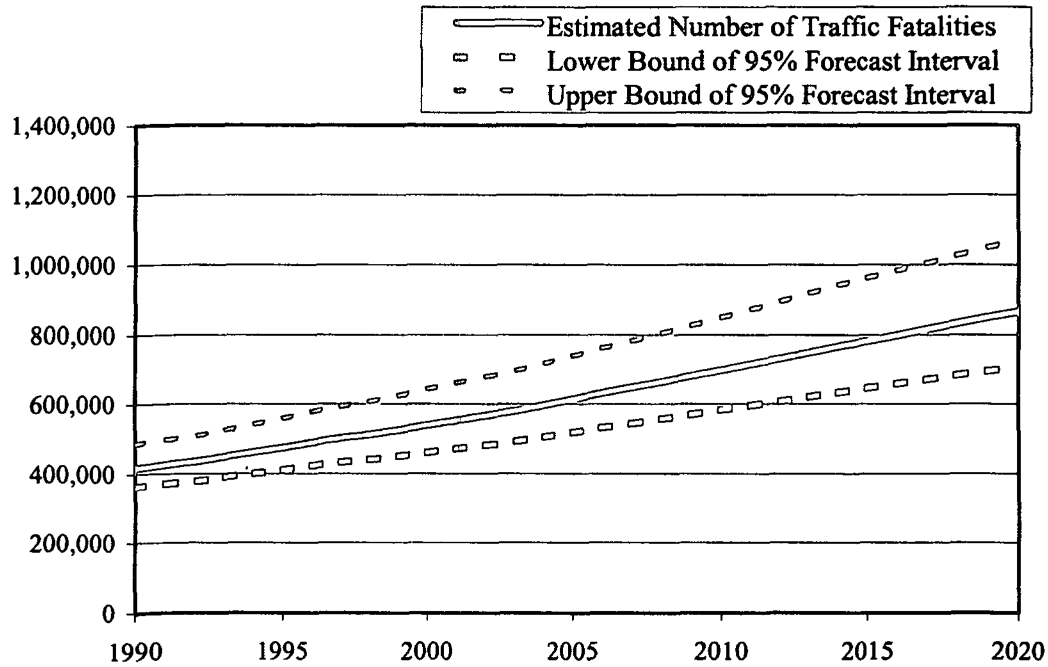
Other studies have made projections of vehicle growth for the automobile fleet only or for passenger cars and commercial vehicles. Since our motor vehicle counts include all buses and two-wheelers, direct comparisons with these studies is difficult. However, our estimates of the total vehicle fleet do exceed their automobile forecasts under all specifications. Under Schafer's (1998) results, the global automobile fleet would more than double from 470 million in 1990 (this includes light trucks for personal travel in the U.S.) to 1.0-1.2 billion automobiles in 2020. This amounts to a 113%-155% increase in total automobiles. The spline model with log-linear regional time trends generates a 140% increase in the total vehicle fleet during the same period (from 609 million to 1.47 billion total vehicles). Because it yields reasonable predictions of the vehicle fleet, as well as reasonable income elasticity estimates, we focus on the spline model with regional, log-linear time trends.

B. Projections of World Traffic Fatalities to 2020

Figure 11 shows predictions of road traffic fatalities for all countries to the year 2020, based on the spline model with log-linear regional time trends. Ninety-five percent confidence levels for our predictions also appear on the graph.[12] We emphasize that these figures represent traffic fatalities unadjusted for under-reporting. To compare these figures with fatality rates from other causes of death, it is necessary to adjust for the fact that (a) the definition of what constitutes a traffic fatality differs across countries and (b) the percentage of traffic fatalities reported by the police also varies across countries.

[12]The model generates point estimates of the log of the fatality rate (ln(Fatalities/10,000 People)). Therefore, the confidence intervals for the predicted values of ln(Fatalities/10,000 People) are symmetric, but the forecast intervals for the total number of fatalities are not.

Figure 11. Global Road Traffic Fatalities, Before Adjusting for Under-Reporting, 1990-2020



Our under-reporting adjustments follow the conservative factors used by Jacobs, Aeron-Thomas and Astrop (2000).[13] To update all point estimates to the 30-day traffic fatality definition, a correction factor of 1.15 was applied in the developing countries and the standard ECMT correction factors were used for the high-income countries.[14] Then the estimates were adjusted to account for general under-reporting of traffic fatalities, by 25% in developing countries and by 2% in highly developed countries.[15] With these adjustments, global road deaths are projected to climb to over 1.2 million by 2020 (a 40% adjustment over the base estimate of 864,000 presented in Figure 11). Although this

[13]Jacobs et al. reviewed numerous underreporting studies and found evidence of underreporting rates ranging from 0-26% in high motorized countries and as high as 351% in less motorized countries. Fatalities in China, for example, were 42% higher in 1994 than reported in official statistics (Liren 1996).
[14] High-Income countries with ECMT correction factors greater than 1 include: France: 1.057, Italy: 1.07, Portugal: 1.3, Japan: 1.3 (ECMT 1998, 2000, 2001).
[15] The 25% under-reporting adjustment is applied to 111 HD2 countries and the 2% adjustment is used for 45 HD1 countries. See Table 7 for regional breakdown of countries.

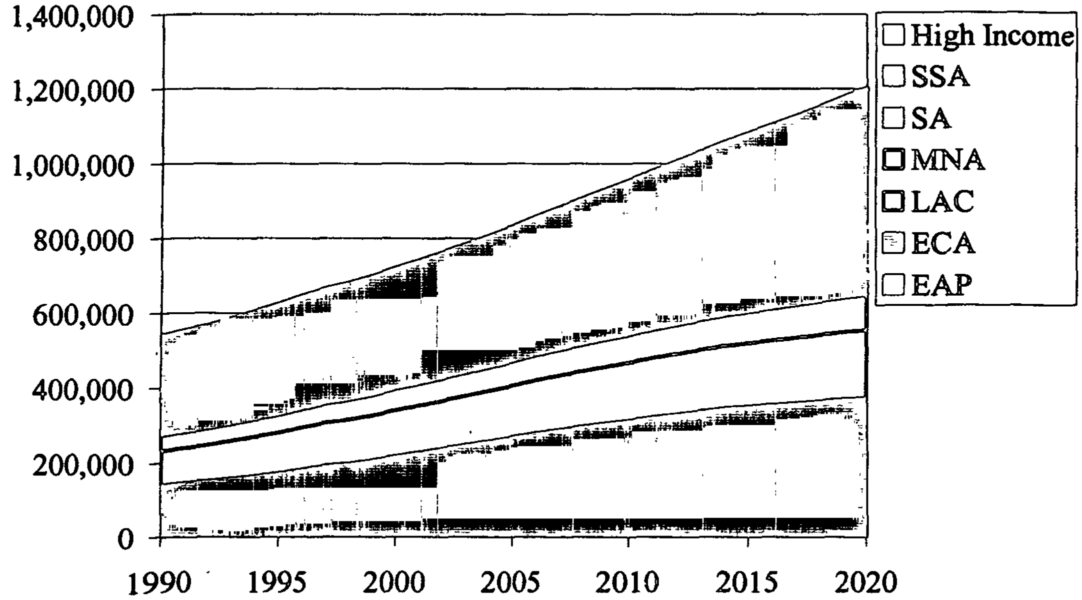
represents a 66% increase over the 2000 world estimate, the trend varies considerably across different regions of the world. Table 8 and Figure 12 indicate that, between 2000 and 2020, fatalities are projected to increase by over 80% in developing countries, but decrease by nearly 30% in high-income countries. Within the developing world, the greatest percentage increases in traffic deaths between 2000 and 2020 will occur in South Asia (144% increase), followed by East Asia and Sub-Saharan Africa (both showing an 80% increase). It is also interesting to note that the number of traffic fatalities per 100,000 persons is predicted to diverge considerably by 2020. By 2020 the fatality rate is predicted to be less than 8 in 100,000 in high-income countries but nearly 20 in 100,000 in low-income countries.

Table 8. Predicted Road Traffic Fatalities by Region (000s), Adjusted for Under-Reporting, 1990-2020

							Fatality Rate (Deaths/100,000 Persons)	
Region*	**No. of Countries**	**1990**	**2000**	**2010**	**2020**	**% change '00-'20**	**2000**	**2020**
EAP	15	112	188	278	337	79.8%	10.9	16.8
ECA	9	30	32	36	38	18.2%	19.0	21.2
LAC	31	90	122	154	180	48.1%	26.1	31.0
MNA	13	41	56	73	94	67.5%	19.2	22.3
SA	7	87	135	212	330	143.9%	10.2	18.9
SSA	46	59	80	109	144	79.8%	12.3	14.9
Subtotal:	121	419	613	862	1,124	83.3%	13.3	19.0
High Income Countries:	35	123	110	95	80	-27.8%	11.8	7.8
World Total:	156	542	723	957	1,204	66.4%	13.0	17.4

*The results are displayed according to the World Bank regional classifications.

Figure 12. Global Traffic Fatalities, Adjusted for Under-Reporting, 1990-2020



The forecasts presented here are significantly lower than the 1990-2020 estimates of road traffic fatalities presented by the World Health Organization in *The Global Burden of Disease (GBD)* (Murray and Lopez 1996). WHO estimates that 1.39 million people will die in road traffic accidents in 2000 and that 2.34 million will die in 2020. The reason for the higher figures is that WHO starts from a higher base (999,000 deaths in 1990). In part, the high GBD base estimate for 1990 may be due to severe data limitations in developing regions. For example, 1990 estimates for the entire Sub-Saharan Africa region were based on data from South Africa only (Cooper et al. 1997, Jacobs et al. 2000). South Africa has by far the highest reported fatality rate (F/P) of nearly 20 SSA countries for which we have 1990 data. Even after adjusting predicted values for non-reporting and under-reporting of fatalities, our SSA estimate is 59,150 deaths for 1990 whereas the GBD baseline is 155,000 for the same year. Despite such large differences between our base estimates and theirs, Murray and Lopez predict that global traffic fatalities will grow at approximately the same rate as the present projections. (Fatalities grow by 62% between 2000 and 2020 according to WHO and by 66% according to our estimates (see Table 8).)

We believe that Murray and Lopez (1996) have over-estimated road traffic fatalities and stand behind the estimates presented here. One reason for this is that our estimate of fatalities in 2000 (723,439) agrees with the TRL estimate of global road deaths for 1999 (Jacobs et al. 2000), i.e., 745,769 fatalities worldwide (low under-reporting adjustment case). The TRL 1999 estimate is based on published 1996 data from 142 countries updated to 1999 levels and adjusted for non-reporting and under-reporting of fatalities. Since this seems to be the most comprehensive, bottom-up approach to estimating the global road death toll to date, we feel that it is the most appropriate estimate against which to compare our projections. Our prediction of traffic fatalities in 2020 (1.2 million deaths worldwide) also lies within the range suggested by TRL for 2020 (1 to 1.3 million deaths), although the latter is not based on a statistical model.

V. Conclusions

The results presented above suggest that, if developing countries follow historic trends, it will take many years for them to achieve the motor vehicle fatality rates of high-income countries. Provided that present policies continue into the future, the traffic fatality rate of India, for example, will not begin to decline until 2042.[16] (The projected

[16] This assumes the annual real per capita GDP growth rate of 3.87% and India's log-linear time trend (from model 8) will continue into the future.

peak corresponds to approximately 24 fatalities per 100,000 persons prior to any adjustment for underreporting but becomes 34 fatalities per 100,000 persons if we maintain the underreporting adjustment factors chosen above.) This is primarily due to the fact that India's per capita income (in 1985 international dollars) was only $2,900 in 2000, whereas F/P peaks at a per capita income of approximately $8,600. Similarly, in Brazil F/P will not peak until 2032, and the model projects over 26 deaths per 100,000 persons as far out as 2050.

In other developing countries, the traffic fatality rate will begin to decline before 2020 but F/P rates will still exceed the levels experienced in High-Income countries today (which average about 11 fatalities per 100,000 persons). Malaysia, for example, is estimated to have over 20 fatalities per 100,000 persons (after adjusting for underreporting) in 2020. If 5.1% growth continues beyond 2020, F/P will reach 11.1 by 2033 (using the same under-reporting adjustment as above); however, if the growth rate decreases to 2.5% after 2020, F/P will reach 11.0 only in 2049.

The predictions in this paper, and the estimates of the income levels at which traffic fatality rates begin to decline, assume the policies that were in place from 1963 through 1999 will continue in the future. Clearly, this may not be the case. In many developing countries fatalities per vehicle could be reduced significantly through interventions that are not reflected in our data. For example, drivers of two-wheelers could be required to wear white helmets, traffic calming measures could be instituted in towns, and measures could be taken to separate pedestrian traffic from vehicular traffic. Whether such measures should be undertaken depends, of course, on their costs and their effectiveness. The purpose of this paper has been to increase awareness of the nature and growing magnitude of the problem.

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VI. Appendix

Data Sources

Data on the number of traffic fatalities and vehicle fleet[17] composition were taken from various editions of the International Road Federation's (IRF) World Road Statistics (WRS) annual yearbooks, 1968-2000. Since each WRS edition contains data for the previous five years, each series was compared across editions to check for accuracy and to ensure that all revisions were properly recorded. Selected IRF data were also compared to numerous regional and country-specific road safety studies. Supplementary data was added from several sources where appropriate, including studies published by the

- Inter-American Development Bank (1998)
- Danish Road Directorate (1998)
- Transportation Research Laboratory (Jacobs et al. 2000)
- United Nations Economic and Social Commission for Asia and the Pacific (1997)
- Statistical Bureau of the People's Republic of China
- Ministry of Transport of Israel (2000)
- European Conference of Ministers of Transport (ECMT)
- Global Road Safety Partnership
- OECD International Road Traffic Accident Database (IRTAD)
- Cross-National Time Series Database (CNTS)
- Statistical Economic and Social Research and Training Centre for Islamic Countries (SESRTCIC)
- Bangladesh Bureau of Statistics
- American Automobile Manufacturers Association

[17] Vehicle counts include all passenger cars, buses, trucks, and motorized two-wheelers.

Population figures came from the U.S. Census Bureau's International Data Base and income data were taken from the World Bank Global Development Network Growth Database Macro Time Series. The income variable most appropriate for this analysis is the Real Per Capita GDP, chain method (1985 international prices) (RGDPCH), since it accounts for differences in purchasing power across countries and allows for comparisons over time.[18]

[18] This series was created from the Penn World Tables 5.6 RGDPCH variable for 1960-1992 and the 1992-1999 data was estimated using the 1985 GDP per capita and GDP per capita growth rates from the Global Development Finance and World Development Indicators.

Table A.1. Classification of Countries for Which Fatalities Are Projected

The number of observations for each country used to estimate the model is given in parentheses after the country name.

Region	Country	
South Asia (SA)		
HD2:	Bangladesh	*(18)*
	Bhutan	
	India	*(27)*
	Maldives	
	Nepal	*(14)*
	Pakistan	*(33)*
	Sri Lanka	*(34)*
East Asia & Pacific (EAP)		
HD1:	Korea, Rep.	*(29)*
HD2:	China	*(22)*
	Fiji	*(15)*
	Indonesia	*(24)*
	Kiribati	
	Lao PDR	
	Malaysia	*(37)*
	Mongolia	*(14)*
	Papua New Guinea	*(12)*
	Philippines	*(18)*
	Samoa	*(13)*
	Solomon Islands	
	Thailand	*(28)*
	Tonga	*(13)*
	Vanuatu	
Middle East & N. Africa (MNA)		
HD1:	Bahrain	*(12)*
HD2:	Algeria	
	Djibouti	
	Egypt	*(11)*
	Iran	
	Iraq	*(11)*
	Jordan	*(32)*
	Morocco	*(34)*
	Oman	
	Saudi Arabia	*(20)*
	Syria	*(22)*
	Tunisia	*(26)*
	Yemen	*(12)*
Latin America &Caribbean (LAC)		
HD1:	Argentina	
	Chile	*(34)*
	Costa Rica	*(14)*
	Uruguay	
HD2:	Antigua & Barbuda	
	Belize	
	Bolivia	
	Brazil	*(16)*
	Colombia	*(27)*
	Dominica	
	Dom. Republic	
	Ecuador	*(13)*
	El Salvador	
	Grenada	
	Guatemala	
	Guyana	
	Haiti	
	Honduras	
	Jamaica	
	Mexico	
	Nicaragua	
	Panama	*(16)*
	Paraguay	
	Peru	*(11)*
	Puerto Rico	
	St. Kitts & Nevis	
	St. Lucia	
	St. Vincent & Grenadines	
	Suriname	
	Trinidad & Tobago	
	Venezuela	
Europe & Central Asia (ECA)		
HD1:	Czech Republic	*(28)*
	Hungary	*(33)*
	Poland	*(19)*
	Slovak Republic	
HD2:	Bulgaria	*(18)*
	Georgia	
	Latvia	*(11)*
	Romania	*(13)*
	Turkey	*(34)*
	Yugoslavia	*(20)*

(Table A.1. continued)

Sub-Saharan Africa (SSA)		**High-Income OECD**	
HD2: Angola		*HD1:* Australia	*(31)*
Benin	*(23)*	Austria	*(37)*
Botswana	*(31)*	Belgium	*(36)*
Burkina Faso		Canada	*(30)*
Burundi		Denmark	*(37)*
Cameroon	*(17)*	Finland	*(37)*
Cape Verde		France	*(37)*
Central African Republic		Germany	*(30)*
Chad		Greece	*(36)*
Comoros		Iceland	*(35)*
Congo, Dem. Rep.		Ireland	*(31)*
Congo, Rep.		Italy	*(35)*
Cote d'Ivoire	*(17)*	Japan	*(37)*
Equatorial Guinea		Luxembourg	*(34)*
Ethiopia	*(30)*	Netherlands	*(37)*
Gabon		New Zealand	*(37)*
Gambia, The		Norway	*(37)*
Ghana		Portugal	*(37)*
Guinea		Spain	*(32)*
Guinea-Bissau		Sweden	*(35)*
Kenya	*(27)*	Switzerland	*(36)*
Lesotho	*(21)*	United Kingdom	*(35)*
Liberia		United States	*(36)*
Madagascar			
Malawi	*(28)*	**Other High-Income**	
Mali		*HD1:* Bahamas	
Mauritania		Barbados	
Mauritius	*(26)*	Bermuda	
Mozambique	*(12)*	Cyprus	*(30)*
Namibia		Hong Kong	*(36)*
Niger	*(24)*	Israel	*(32)*
Nigeria	*(15)*	Kuwait	
Rwanda		Malta	
Sao Tome &Principe		Qatar	
Senegal	*(19)*	Singapore	*(16)*
Seychelles		Taiwan	*(25)*
Sierra Leone	*(17)*	U.A.E.	
Somalia			
South Africa	*(35)*		
Sudan			
Swaziland	*(13)*		
Tanzania			
Togo	*(16)*		
Uganda	*(19)*		
Zambia	*(13)*		
Zimbabwe	*(15)*		
Total:	**156 Countries, 2,178 Country-year Observations**		

Notes for Table A.2:

Standard Errors are given in parentheses.

The constant term reflects the intercept term for India. Country fixed effects were included in all regressions but are not displayed here.

Model Specifications:

1. Quadratic, common linear time trend
2. Quadratic, common log-linear time trend
3. Quadratic, regional linear time trends
4. Quadratic, regional, log-linear time trends
5. Spline, common linear time trend
6. Spline, common log-linear time trend
7. Spline, regional linear time trends
8. Spline, regional, log-linear time trends

Table A.2. Regression Results from Fatalities/Population Models

Independent Variables	Quadratic				Spline			
	1	2	3	4	5	6	7	8
lnY	7.7500*	7.8146*	5.1714*	6.1926*				
	(0.2243)	*(0.2223)*	*(0.3058)*	*(0.2886)*				
$(\ln Y_{it})^2$	-0.4510*	-0.4607*	-0.2785*	-0.3578*				
	(0.0137)	*(0.0134)*	*(0.0191)*	*(0.0177)*				
lnY for: $1- $938					1.6837*	1.6067*	1.4445*	1.2526*
					(0.1432)	*(0.1434)*	*(0.1400)*	*(0.1439)*
$938- $1,395					1.1798*	1.1445*	1.1193*	1.0604*
					(0.1266)	*(0.1258)*	*(0.1322)*	*(0.1283)*
$1,395- $2,043					0.5064*	0.4277*	0.5119*	0.3256*
					(0.1219)	*(0.1209)*	*(0.1250)*	*(0.1278)*
$2,043- $3,045					0.9199*	0.8177*	0.9757*	0.7651*
					(0.1304)	*(0.1302)*	*(0.1299)*	*(0.1345)*
$3,045- $4,065					0.6995*	0.6221*	0.9602*	0.7007*
					(0.1526)	*(0.1520)*	*(0.1492)*	*(0.1495)*
$4,065- $6,095					0.3225*	0.2758*	0.6021*	0.3903*
					(0.1146)	*(0.1130)*	*(0.1119)*	*(0.1107)*
$6,095- $8,592					-0.0477	-0.1119	0.2579*	0.0746
					(0.1318)	*(0.1315)*	*(0.1288)*	*(0.1299)*
$8,592-$10,894					-0.7910*	-0.9382*	-0.2074	-0.5422*
					(0.1645)	*(0.1658)*	*(0.1633)*	*(0.1668)*
$10,894-13,234					-1.5720*	-1.6733*	-0.6682*	-1.3381*
					(0.1952)	*(0.1904)*	*(0.1999)*	*(0.1886)*
>$13,234					-1.1509*	-1.2061*	-0.5216*	-0.9964*
					(0.1637)	*(0.1603)*	*(0.1637)*	*(0.1571)*
Turning Point (1985$int'l)	$5,385	$4,825	$10,784	$5,738	$6,095	$6,095	$8,592	$8,592
95% C.I.:	[$4977, $5826]	[$4489, $5186]	[$8644, $13455]	[$5141, $6403]				
Common time trend: t	-0.0010	0.0346*			0.0013	0.0555*		
	(0.0010)	*(0.0123)*			*(0.0010)*	*(0.0122)*		
Regional t: EAP			0.0054*	0.2377*			0.0065*	0.2573*
			(0.0029)	*(0.0417)*			*(0.0029)*	*(0.0416)*
ECA			-0.0100*	0.0162			-0.0126*	-0.0305
			(0.0032)	*(0.0399)*			*(0.0032)*	*(0.0403)*
India			0.0194*	0.2789*			0.0225*	0.3189*
			(0.0048)	*(0.0591)*			*(0.0048)*	*(0.0579)*
LAC			0.0145*	0.3100*			0.0120*	0.2639*
			(0.0032)	*(0.0625)*			*(0.0032)*	*(0.0615)*
MNA			-0.0093*	-0.0301			-0.0067*	0.0106
			(0.0023)	*(0.0301)*			*(0.0025)*	*(0.0324)*
SA			-0.0015	0.0361			0.0041	0.0956*
			(0.0031)	*(0.0389)*			*(0.0032)*	*(0.0388)*
SSA			0.0101*	0.1468*			0.0106*	0.1609*
			(0.0013)	*(0.0191)*			*(0.0013)*	*(0.0186)*
High Income			-0.0191*	-0.0783*			-0.0154*	-0.0567*
			(0.0016)	*(0.0177)*			*(0.0017)*	*(0.0176)*
F statistic on regional ts:			$F_{8,2102}$ = 35.60	$F_{8,2102}$ = 19.72			$F_{8,2094}$= 29.50	$F_{8,2094}$= 20.99
constant	-32.948*	-33.046*	-23.796*	-27.427*	-12.550*	-12.149*	-11.359*	-10.462*
	(0.9128)	*(0.9092)*	*(1.1952)*	*(1.1416)*	*(0.9606)*	*(0.9596)*	*(0.9360)*	*(0.9599)*
Adjusted R2:	0.8455	0.8460	0.8634	0.8557	0.8554	0.8567	0.8695	0.8656
No. of Countries: 88, No. of observations: 2200								

Table A.3. Forecasts of Real Per Capita GDP Annual Growth Rates (%), 2000-2020

Region/Country	2000	2001	2002-2020
South Asia	3.0	2.8	3.8
India	3.3	2.8	
East Asia and Pacific	6.4	3.6	5.1
China	7.0	6.4	
Korea, Rep.	7.9	1.7	
Indonesia	3.5	2.1	
Europe and Central Asia	6.1	1.9	3.3
Russian Federation	8.6	5.0	
Turkey	5.5	-8.7	
Poland	4.1	1.4	
Latin America and the Caribbean	2.2	-0.7	2.1
Brazil	3.0	0.2	
Mexico	5.2	-1.3	
Argentina	-1.7	-3.2	
Middle East and North Africa	1.9	1.5	1.4
Saudi Arabia	0.7	-1.5	
Iran	3.5	2.5	
Egypt	3.5	2.7	
Sub-Saharan Africa	0.5	0.3	1.3
South Africa	1.4	1.0	
Nigeria	0.4	0.3	
High-income Economies			
Industrial			
G-7	2.7	0.3	2.1
US	3.2	0.3	2.0
Japan	1.5	-0.9	2.0
G-4 Europe	3	1.3	2.3
Germany	3.1	0.7	2.1
Euro Area	3.3	1.4	2.5
Non-G7 Industrial	3.5	1.6	2.7
Other High-income	4.7	-0.7	2.8
Asian NIEs (KOR, HKG, SGP)	6.4	-0.7	3.4

Source: World Bank Global Economic Prospects 2002.

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