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Road Infrastructure and Economic Development

Some Diagnostic Indicators

Cesar Queiroz
and
Surhid Gautam

The average stock of paved roads per million inhabitants in high-income economies is 59 times that in low-income economies. And those roads are in better condition than the ones in low-income economies.

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This paper — a joint product of the Infrastructure Operations Division, Western Africa Department, and the Transport Division, Infrastructure and Urban Development Department — is part of a larger effort to define the macroeconomic linkages and impact of infrastructure. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Marie Laygo, room H3-151, extension 31261 (June 1992, 35 pages).

Queiroz and Gautam investigate the association between per capita income and the magnitude and quality of road infrastructure. They adopt an empirical approach, directly comparing or correlating a country's income with selected variables associated with existing road networks.

Cross-section analysis of data from 98 countries, and time-series analysis of U.S. data since 1950, show consistent and significant associations between economic development (per capita GNP) and road infrastructure (per capita length of paved road network).

The data show that the per capita stock of road infrastructure in high-income economies is dramatically greater than in middle- and low-income economies. For instance, the average density of paved roads (km/million inhabitants) varies from 170 in low-income economies to 1,660 in middle-income and 10,110 in high-income economies. That is, the average density of paved roads in high-income economies is 59 times that in the low-income group.

Road conditions also seem to be associated with economic development: The average density of paved roads in good condition varies from 40 km/million inhabitants in low-income economies to 470 in middle-income and 8,550 in high-income economies.

The empirical information presented can be used as indicators of areas of weakness or strength in a country's stock of road infrastructure.

ROAD INFRASTRUCTURE AND ECONOMIC DEVELOPMENT: SOME DIAGNOSTIC INDICATORS

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ROAD INFRASTRUCTURE AND ECONOMIC DEVELOPMENT: SOME DIAGNOSTIC INDICATORS

by Cesar Queiroz and Surhid Gautam

An investigation of the association between per capita income and the magnitude and quality of road infrastructure is carried out. The approach adopted is empirical in that selected variables on existing road networks are directly compared or correlated with a country's income. Cross-section analysis of data from 98 countries, and time-series analysis of U.S. data since 1950 showed consistent and significant associations between economic development, in terms of per capita gross national product (GNP), and road infrastructure, in terms of per capita length of paved road network. The data show that the per capita stock of road infrastructure in high-income economies is dramatically greater than in middle and low-income economies. For instance, the average density of paved roads (km/million inhabitants) varies from 170 in low-income economies to 1,660 in middle and 10,110 in high-income economies, the latter being 5,800 percent higher than the low-income group. Road condition also seems to be associated with economic development: the average density of paved roads in good condition (km/million inhabitants) varies from 40 in low-income economies to 470 in middle and 8,550 in high-income economies. The empirical information presented can be used as indicators of areas of weaknesses or strengths in a country's road infrastructure stock.

Introduction

Road transport is an important sector of economic activity, especially in developing countries, where it plays an essential role in marketing agricultural products and providing access to health, education and agricultural inputs and extension services. The impact of road transportation in developed regions is also significant. As an example, in the United States it accounts for 15 per cent of the Gross National Product (GNP) and 84 percent of all spending on transportation (1). An efficient road system gives a country a competitive edge in moving goods economically. Conversely, lack of accessibility or poor road conditions are barriers to agriculture, industry and trade, and may hinder the entire development effort. Nevertheless, the contributions of transport to national development may be difficult to quantify in economic terms.

This paper presents information which can be used as indicators of areas of weaknesses or strengths in a country's road infrastructure stock. The approach adopted is empirical in that selected variables on existing road networks are directly compared or correlated with a country's income. As pointed out by Owen (2), comparisons of income and road infrastructure are not meant to imply that a road by itself is capable of developing a country or region, but that it is a necessary element in the development process.

How Roads Influence Development

Transportation plays a multifaceted role in the pursuit of development objectives. Restriction of accessibility limits efficient factor mobility, and defers the transfer of human and material resources to places where they can be employed most productively. Conversely, transportation development helps to attain an efficient distribution of population, industry and income.

Rural areas with low standards of living are characteristically those with inadequate methods of moving people and goods, probably because of deficient access between villages and markets, schools, medical, economic, administrative and social services which affect the day to day lives of rural people (3). Transportation is an essential ingredient of almost everything man does to supply himself with the necessities of life. Road transport is particularly important for developing countries, where it provides about 80 to 90 percent of the total inland and/or border crossing transport of people and goods. An effective road network can hasten progress in agricultural and rural development, industry and trade, the viability of urban areas, and the expansion of jobs, education and personal opportunity (4). The World Bank's Long-Term Perspective Study (5) emphasizes that although better market incentives (especially related to prices and inputs) to farmers remain important factors in agriculture, the effects of these would be blunted if the physical barriers and economic costs of transporting goods to and from markets remain high.

Sources of Data

Data used in this analysis were gathered from different sources. GNP and population data come from the statistical annexes of "Sub-Saharan Africa - From Crisis to Sustainable Growth" (5) and the World Development Report 1990 (6). The data on road length, classification and condition were compiled from different World Bank reports (7, 8), "World Road Statistics 1985-1989" (9), Highway Statistics (10), Statistical Abstracts of the United States (11), Annual Bulletin of Transport Statistics for Europe (12), and World Transport Data (13).

The main variables included in this study are defined as follows. Gross National Product (GNP) is the measurement of a nation's total market value of the final goods and services that are produced in the economy during a given time period, normally one year. GNP per capita is a country's gross national product divided by its population, henceforth denoted by PGNP. Spatial road density is a country's road length per land area, and road density is per capita length of the road network.

Road conditions are defined as in the World Bank policy paper on road deterioration (5): (a) Good: paved roads substantially free of defects and requiring only routine maintenance, or unpaved roads needing only routine grading and spot repairs; (b) Fair: paved roads having significant defects and requiring resurfacing or strengthening, or unpaved roads needing reshaping or resurfacing (regraveling) and spot repair of drainage; and (c) Poor: paved roads with extensive defects and requiring immediate rehabilitation or reconstruction, or unpaved roads needing reconstruction and major drainage works.

The sample countries for which the required data was available are listed in the Appendix. Naturally, the information on the total length of paved and unpaved road networks is deemed more reliable than the percentages in good, fair or poor condition. Information on road condition from different countries is often collected by different methods and on the basis of different definitions.

Cross-Section Analysis

We employ an empirical approach to explore the association between road infrastructure and economic development. Different regression analyses were carried out using GNP/capita as dependent variable and selected indicators of magnitude and condition of road networks as independent variables. Independent variables used in the analyses included: (a) spatial road density (i.e., road length per land area) of paved and unpaved roads classified in good, fair or poor condition; and (b) road density or per capita length (km/million population) of paved and unpaved roads in good, fair or poor condition.

A sample of the relationships resulting from analyses of the data described above, with per capita GNP as the dependent variable, is given in Table 1. The most significant relationship was between per capita GNP and density of paved road network. Figure 1 shows this relationship for 98 developed and developing countries in 1988, along with the scatter diagram. The resulting correlation equation is:

$$PGNP = 1.39 \times LPR$$

where PGNP is per capita GNP ($/inhabitant) and LPR is the per capita length of paved roads (km/million inhabitants). The R squared value is 0.76, the number of degrees of freedom is 97, and the t-statistic of the coefficient is 20.7. By changing units in the above equation, one can show that there exists on the average $1.39 of per capita GNP for each millimeter of paved road in a country. A less significant regression equation (with an R squared value of 0.50) was obtained between per capita GNP and the spatial density of paved roads (Figure 2): $LGNP = 2.25 + 0.49 \times LD$, where LGNP is the logarithm of per capita GNP ($/inhabitant), and LD is the logarithm of spatial density of paved roads (km/1,000 square km of land area); the number of degrees of freedom is 96 and the t-statistic of the coefficient is 9.6.

The methodological, conceptual, and statistical problems over cross-country studies of growth are well described by Levine and Renelt (14). Notwithstanding these problems, the relationship described above seems quite reliable because of the relatively large sample size (98 countries) and its statistical significance. It is also relatively consistent with the results of a time-series analysis of U.S. data, as shown later in the paper.

The coefficient in the above equation (i.e. 1.39) can be used as a rough indicator of the adequacy of paved roads stock in a country. Countries where the ratio between per capita GNP and paved roads density is well above 1.39 are relatively underendowed in terms of their stock of paved roads. Such is the case for example of South Korea (ratio=15.5) and Bolivia (ratio=5.0). Conversely, countries with low ratios can be viewed as relatively overendowed in terms of paved roads stock. This is the case, for example, of Venezuela: with a ratio of 0.3, this country should probably concentrate more in maintaining the existing network instead of paving new roads.

Road costs vary widely across countries and over time and depend on a number of circumstances. Costs of new road construction can vary from less than $50,000 a kilometer for a gravel road to more than $1 million a kilometer for a four-lane access-controlled divided highway (7). If we assume that paved roads cost $300,000/km (which is reasonable for developing countries), the equation PGNP=1.39LPR can be used to show that on the average there exists $4.60 of per capita GNP for each dollar invested on paved roads:

$$PGNP = 4.6 \times I$$

where I is the investment in paved roads (in dollars), i.e., the product of the length of paved roads and $300,000/km.

A rationale for the equation above is that "infrastructure investments contribute to economic growth by increasing the productivity of other economic inputs" (15). Although correlation does not imply causality, it is significant that economic development and road infrastructure are closely associated.

A fundamental problem with cross-country estimation of supply functions is the establishment of the direction of causality. Supply functions implicitly assume that such direction runs from road stock to output or productivity. Therefore, causality is an interesting issue to be highlighted for future research: Does an increase in road stock cause growth or is it the other way around? On a technical point an argument could be made that increasing GNP results in less restricted maintenance and development budgets and hence improved road infrastructure. To prove that better roads lead to better GNP growth is not within the scope of this paper. If further research proves this beyond any doubt, the above equation could be interpreted as follows: an investment of $1 to expand the paved road network of a country corresponds, on the average, to an increase of $4.6 (or about five times) of the country's GNP. Lest the unwary reader interprets this as a rate of return of 460 percent, one should bear in mind that roads stock is just one of a large number of inputs required to produce a certain level of output. Without causality, the relationship PGNP = 4.6xI merely implies that for every $1 of a country's paved road capital stock, we observe $4.6 of GNP (a brief discussion of causality is presented later).

Moreover, the importance of unpaved roads should not be underestimated. For example, in many agricultural areas, unpaved roads are the feeder system critical to the marketing of the agricultural surplus which indirectly supports the higher productive urban economy. The density of unpaved roads was not included in the above equations because of its high correlation with the density of paved roads. It seems therefore prudent to interpret LPR as a proxy for a country's road stock, both paved and unpaved.

Time-Series Analysis of U.S. Data

A vast amount of historic data is available on the road network and economy of the United States (10, 11). By carrying out a time-series analysis of U.S. data from 1950 to 1988, we found a significant positive relationship between per capita GNP (PGNP, in $1,000/inhabitant, using 1982 constant dollars) and density of paved roads (LPR, in km/1,000 inhabitants):

$$PGNP = -3.39 + 1.24LPR$$

with an R squared value of 0.93; the number of degrees of freedom is 37, and the t-statistic of the coefficient is 21.4 (Figure 3). The intercept (i.e., -3.4) in the above equation is difficult to interpret. However, a null GNP is well beyond the inference space. Moreover, if we force the equation through the origin, the resulting regression equation is still significant: PGNP = 0.97LPR, with an R squared of 0.88.

An interesting exercise consists in running regressions between PGNP and LPR using different time lags: we found the highest correlation existed when PGNP for a given year was associated with LPR four years earlier (Figure 4). This seems to indicate that paved roads had an effect on GNP, but there was a time lag of about four years between construction and ultimate impact. This four-year time lag is in broad agreement with the "half a decade" lag period observed by Aschauer (16). Aschauer has shown that productivity (i.e., output per unit of private capital and labor) is positively related to government spending on infrastructure, including roads. Analyzing data from the United States for the period 1949 to 1985, he observed that underinvestment in infrastructure started in about 1968, and the effects of deterioration became evident half a decade later, when a productivity slump began in the U.S.

It should be noted, however, that the above result was obtained for only one country, and using only one independent variable in the equation. This is an area specifically recommended for further research, in that similar exercises could be carried out for other countries with inclusion of additional explanatory variables in the equations.

Comparison of Cross-Section and Time-Series Analyses

It is interesting to compare the equations resulting from the cross-section analysis of data from 98 countries (circa 1988) and from the time-series analysis of the U.S. data (1950 to 1988). The time-series equation PGNP = -3.4 + 1.24LPR was derived with constant 1982 dollars. To make it comparable with the cross-sectional equation, it should be expressed in 1988 constant dollars taking into account the change in the GNP implicit price deflator between 1982 and 1988, i.e., a factor of 1.213 (11). The resulting equation is:

$$PGNP_{88} = -4.1 + 1.50 \times LPR$$

where $PGNP_{88}$ is real per capita GNP (1988 $1,000/inhabitant) and LPR is the per capita length (or density) of paved roads (km/thousand population).

The inference spaces for both equations can be approximately defined by: (a) cross-sectional analysis: paved road density between 60 and 20,000 km/million population; and (b) time-series analysis: paved road density between 8,000 and 20,000 km/million population. Figure 5 depicts the two equations according to their inference space. As can be seen in the figure, there is relatively good consistence between both equations.

Comparison of Road Supply in the World Economies

A comparison between the supply and condition of paved road networks in 98 developing and developed countries is shown in Figure 6. The country groups in the figure are defined as (6):

(a) Low-income economies are those with a GNP per capita of $545 or less in 1988;

(b) Middle-income economies are those with a GNP per capita of more than $545 but less than $6,000 in 1988; and

(c) High-income economies are those with a GNP per capita of $6,000 or more in 1988.

For the analyses described in this paper, data was available for 42 low-income economies (average per capita GNP of $320); 43 middle-income economies (average PGNP=$1720/capita); and 13 high-income economies (average PGNP=$17,420/capita).

As shown in Figure 6, the supply of road infrastructure in high-income economies is dramatically higher than in middle and low-income economies. For instance, the average density of paved roads (km/million inhabitants) varies from 170 in low-income economies to 1,660 (plus 876 percent) in middle and 10,110 in high-income economies, the latter being 5,800 percent higher than the low-income group. Road condition is also associated with economic development: the average density of paved roads in good condition (km/million inhabitants) varies from 40 in low-income economies to 470 in middle and 8,550 in high-income economies (an increase of 21,000 percent over the low-income group).

In the particular case of Africa, there is a similar trend between low and middle-income economies, as shown in Figure 7. While the increase in average per capita GNP between the two country groups is 220 percent, the per capita length of paved roads in good condition increases by about 370 percent with the increase in income.

The results above seem to indicate that economic development has a link with paved roads density, and also to the maintenance standards of these roads. A similar trend exists for unpaved roads, since there is high correlation between the extent of a country's paved and unpaved road networks.

The limited resources devoted to the upkeep of road networks in developing countries in the last decade, together with the growth of heavy freight traffic, have created a large backlog of road maintenance and rehabilitation needs. In several countries many kilometers of roads have deteriorated from good to fair and from fair to poor condition. It is not exceptional for sections of main trunk roads to have lost most or all of their black top, thus causing a shrinkage of a country's passable road network. Although many other factors are involved, several countries where GNP per capita has decreased in recent years have also faced significant deterioration in their road networks. This trend is illustrated in Figure 8, which shows a decline in real per capita GNP and road condition between 1984 and 1989 for several African countries.

Conversely, several countries that were able to improve their road infrastructure in the same period had also an increase in real income per capita (Figure 9). Ghana is a good example: From 1984 to 1989, its per capita GNP increased by 11 percent--from $350 annually to $390; in the same period, the density of paved roads in good condition expanded by 102 percent, from 56 to 113 km per million inhabitants (Figure 9). On the basis of the findings described above, improved road infrastructure in Ghana is likely to contribute to further economic growth.

Regarding the macroeconomic linkages of infrastructure, authors such as Ingram (15) assert that the conceptual link between infrastructure (including roads) and the supply side of the economy is as follows: (a) reductions in the stock of infrastructure capital can shift the production possibility frontier inward and reduce the economy's possible output; and (b) increases in infrastructure capital can shift the production possibility frontier outward and provide a source of growth for the economy. This linkage is in line with the data shown in Figures 8 (reduction in both per capita GNP and density of paved roads in good condition) and 9 (increase in both per capita GNP and density of paved roads in good condition).

A Discussion of Causality

Assessing the impact of road infrastructure on economic performance is not straightforward because many other factors are involved. As we mentioned earlier, direction of causation between changes in income and changes in road infrastructure are not clear cut. One could argue that causation in the equations described in this paper could run in either direction. However, there are some indications that roads should precede development, of which a few examples are:

(a) In estimating the aggregate supply response of agriculture, Chhibber (17) showed that both price and non-price variables have significant effect. Although he did not explicitly consider a proxy for road stock in his analyses, it was implied that non-price variables included transport and communication facilities.

(b) Binswanger (18) found that the lack of roads is a significant constraint on the supply response of agriculture.

(c) In India, a Central Road Research Institute study by Dhir, Lal and Mital (19) has shown that literacy, agricultural yield and health care increase with road density.

(d) Shah (20) used a restricted equilibrium framework to estimate the contribution of public investment in infrastructure to private sector profitability in Mexico. He concluded that a policy emphasis should be to upgrade the public infrastructure (including roads) so that scale economies could be exploited in the future.

(e) The linkage between roads and development has also been acknowledged by country leaders. As an example, President Bush has asserted that the interstate highway system fueled development in the U.S. for a generation, uniting the states as never before - economically, politically, socially (21).

(f) Hirschman (22) pointed out that highway construction can be conceived as the laying down of a "prerequisite" for further development. As such, it permits and invites, rather than compel, other activities to follow suit. This is in line with Owen's (2) assertion that comparisons of income and road infrastructure are not meant to imply that a road by itself is capable of developing a country or region, but that it is a necessary element in the development process.

(g) Using US data in the period 1949 to 1985, Aschauer (16), has shown that productivity (i.e., output per unit of private capital and labor) is positively related to government spending on infrastructure, including roads. He also observed that underinvestment in the U.S. infrastructure started in about 1968, and the effects of deterioration became evident half a decade later. In a different paper, Aschauer (23) offered several checks on the direction of causation, concluding that increases in public capital stock lead to higher total factor productivity, which is a proxy for per capita income.

(h) Using 1965 data from 47 less developed countries and 19 developed countries, Antle (24) demonstrated the importance of transportation and communication facilities for raising aggregate agricultural productivity.

(i) An analysis of the economic rates of return of World Bank financed projects in the period 1968 to 1984, carried out by Israel (25), indicates that transportation investments, particularly roads, are among the most productive.

Therefore, the notion that road infrastructure is a necessary element in the development process is supported by several pieces of research. However, many factors can influence the impact of roads on income. In particular, an exploration of the linkages between policy distortions and the actual outcome of infrastructure investments, carried out by Kauffman (26), concluded that a distorted policy environment reduced significantly the ex-post return of the investments. A good example of policies that would probably increase the impact of road investments on productivity was given by Small, Winston and Evans (27). Their policy recommendations include a set of pavement-wear taxes for heavy trucks, a set of congestion taxes for all vehicles, and a program of optimal investments in road durability. Such policies are based on two economic principles: efficient pricing to regulate demand for highway services and efficient investment to minimize the total public and private cost of providing them (27).

Conclusions

The analyses in this paper show that there is a statistically significant relationship between road infrastructure and economic development on a worldwide basis: cross-section analysis of data from 98 countries (circa 1988), and time-series analysis of U.S. data between 1950 and 1988 showed significant relationships between per capita gross national product (PGNP) and density (i.e., per capita length, LPR) of paved road network. Moreover, there is relatively good consistency between the regression equations from cross-section and time-series analyses, when compared according to their respective inference space. Because of the high correlation between the densities of paved and unpaved roads, LPR should be interpreted as a proxy for a country's road stock, both paved and unpaved.

The per capita stock of road infrastructure in high-income economies is dramatically greater than in middle and low-income economies. For instance, the average density of paved roads (km/million inhabitants) varies from 170 in low-income economies to 1,660 (plus 876 percent) in middle and 10,110 in high-income economies, the latter being 5,800 percent higher than the low-income group. Road condition also seems to be associated with economic development: the average density of paved roads in good condition (km/million inhabitants) varies from 40 in low-income economies to 470 in middle and 8,550 in high-income economies. There is also a clear contrast between road infrastructure and income in low and middle-income economies in Africa: while the difference in average per capita GNP between the two country groups is 220 percent, the density of paved roads in good condition varies by about 370 percent from one group to the other, using 1989 data.

Causality is an issue highlighted for future research: Does an increase in road stock cause growth or is it the other way around? Assessing the impact of the supply and quality of road infrastructure on economic performance is a complex area of research with potentially important implications on the international infrastructure lending strategy to developing countries.

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Appendix

List of countries with data available on population, per capita gross national product, length of paved and unpaved road networks, and road condition. The vast majority of the data was obtained for 1988. However, for a few countries 1988 data was not available; then 1987 or 1989 data was used. Countries are sorted by per capita GNP. The appendix includes three annexes: (1) data on population, per capita GNP and paved and unpaved road density; (2) data on land area, per capita GNP and paved and unpaved road spatial density; and (3) U.S. data used in the time-series analysis.

Relationship between per capita GNP and Paved Road Density (circa 1988)

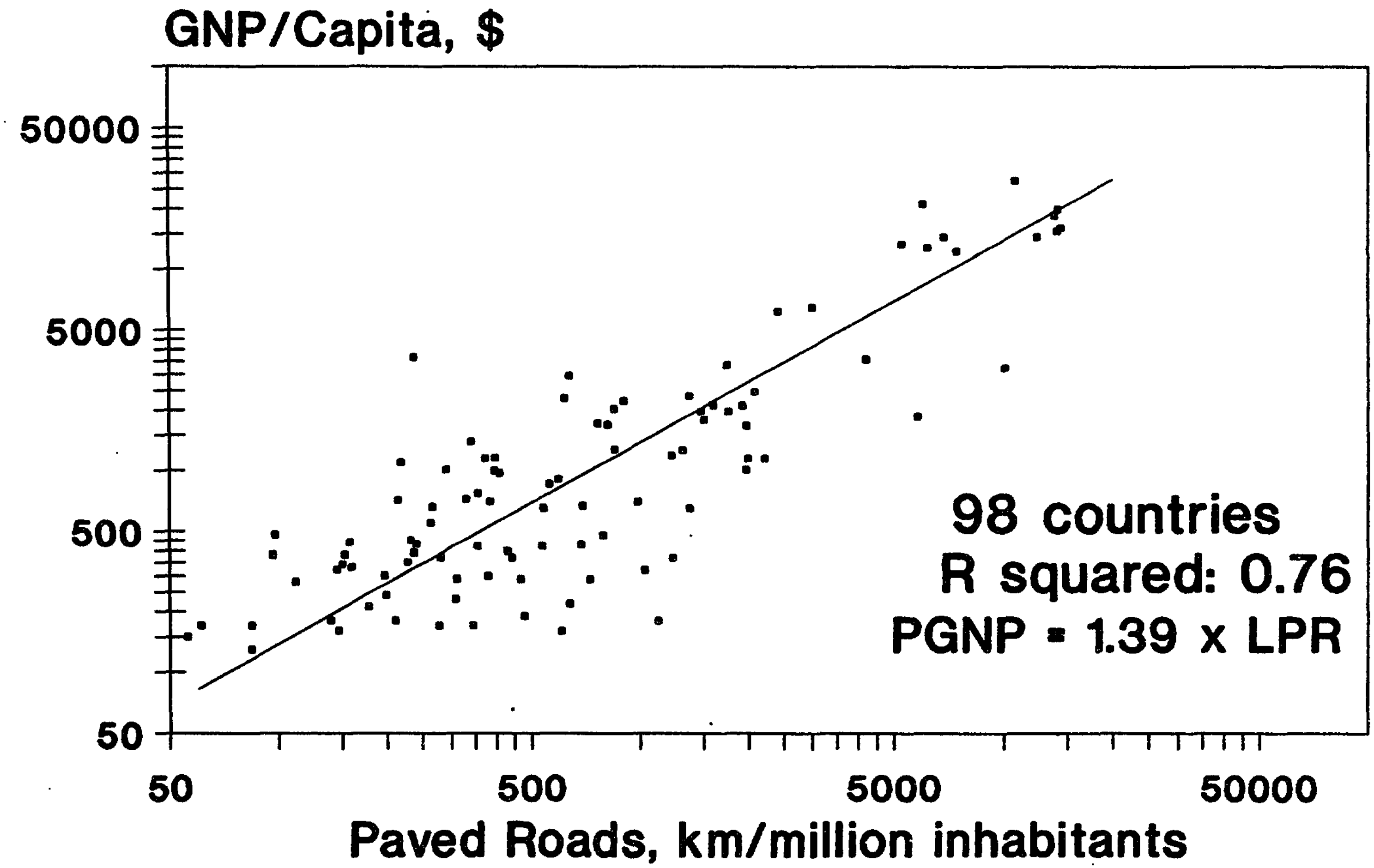

FIGURE 1

Relationship between per capita GNP and Paved Road Spatial Density (circa 1988)

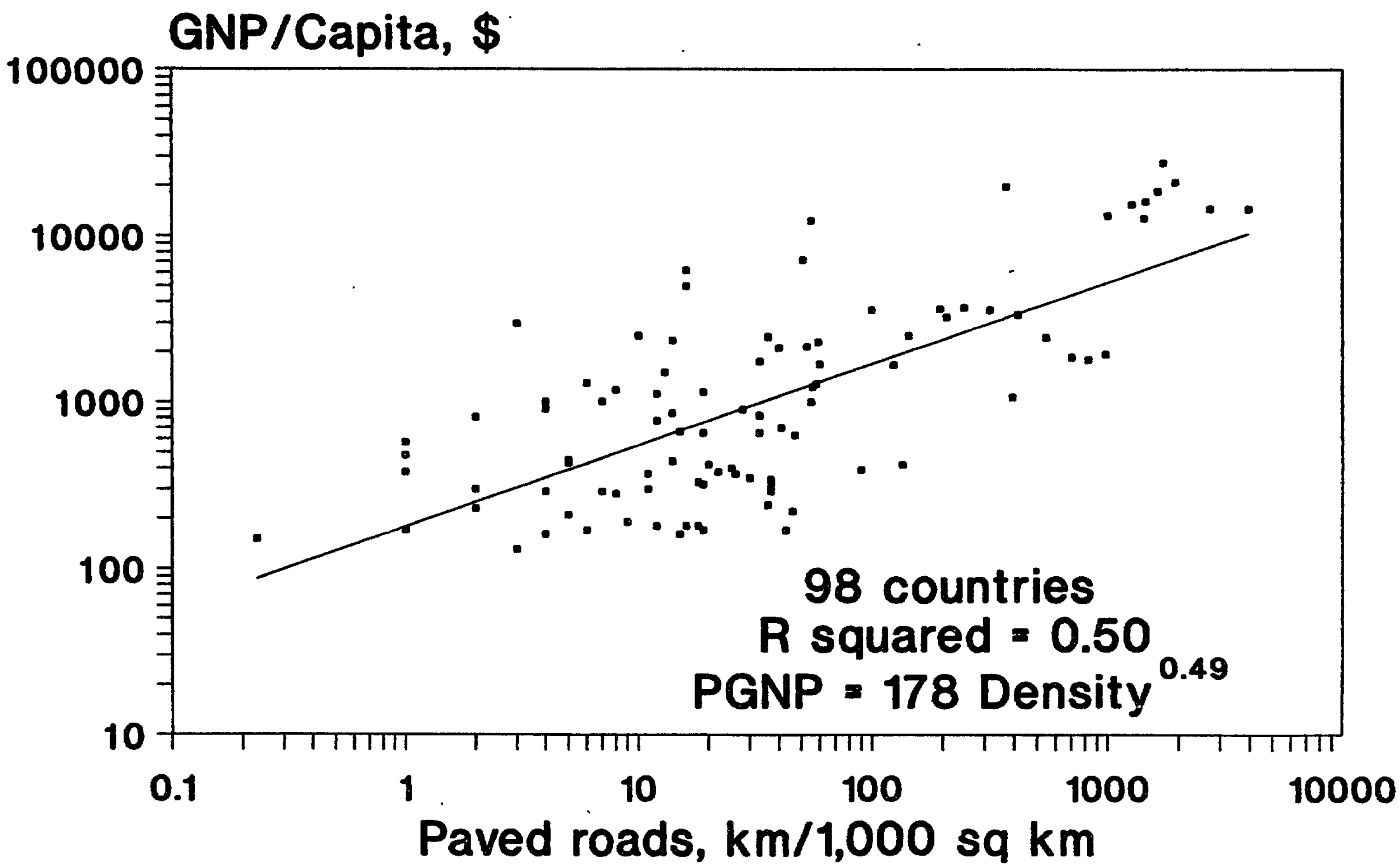

FIGURE 2

Relationship Between Real per Capita GNP and Paved Road Density in the U.S.

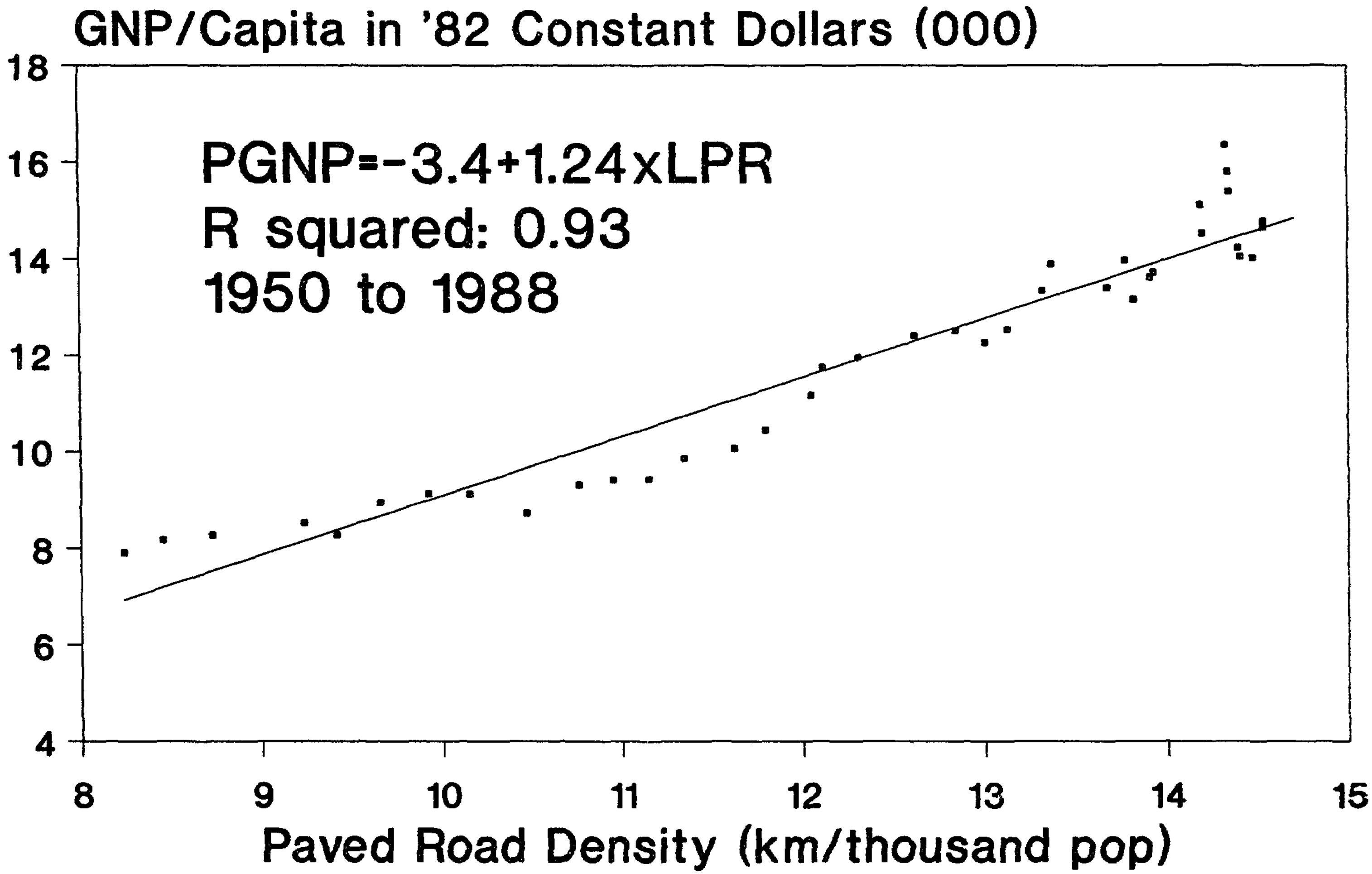

FIGURE 3

Correlation Between Real per capita GNP and Lagged Paved Road Density in the U.S. for the Equation PGNP=aLPR

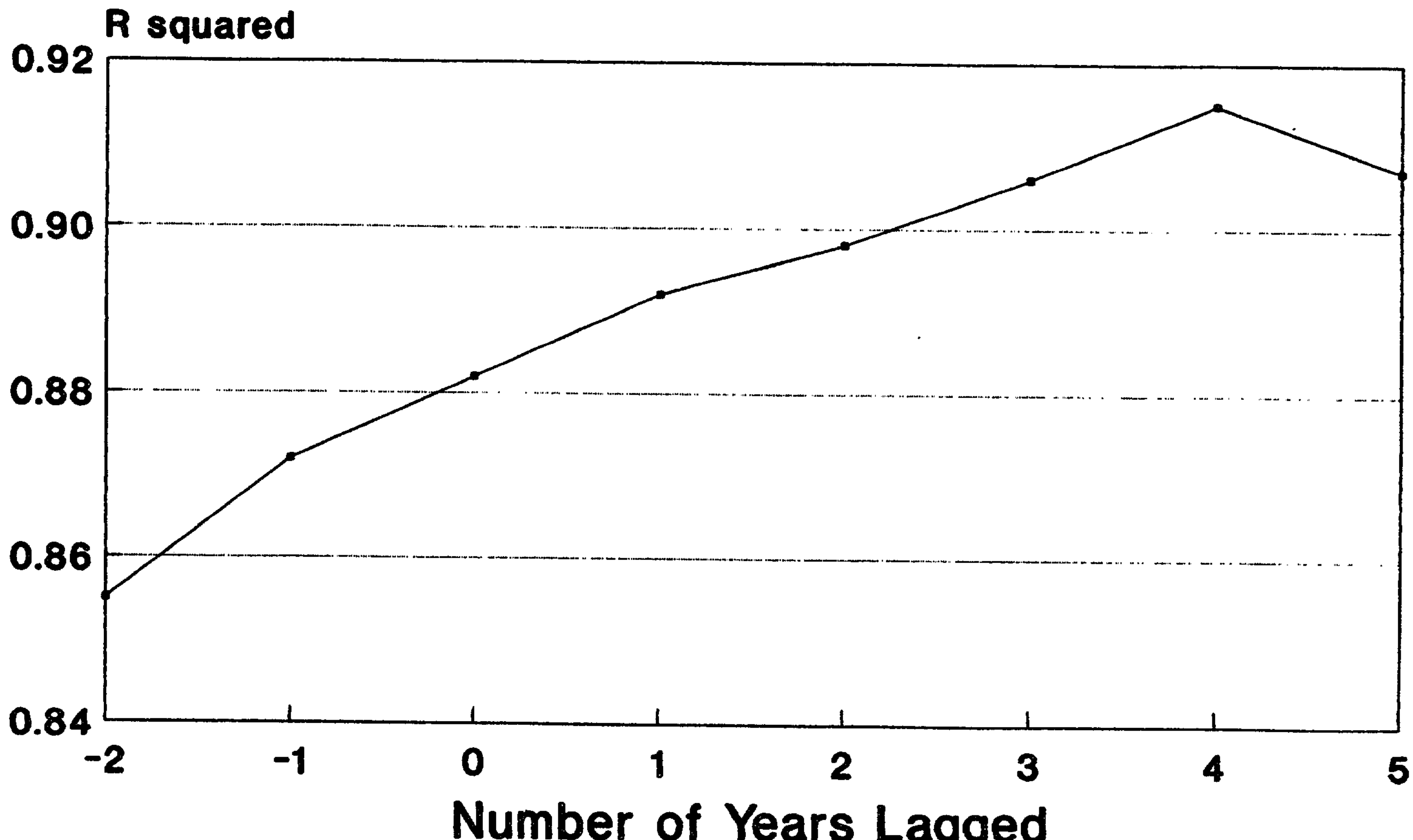

FIGURE 4

Comparison Between Cross Section and Time Series Analyses

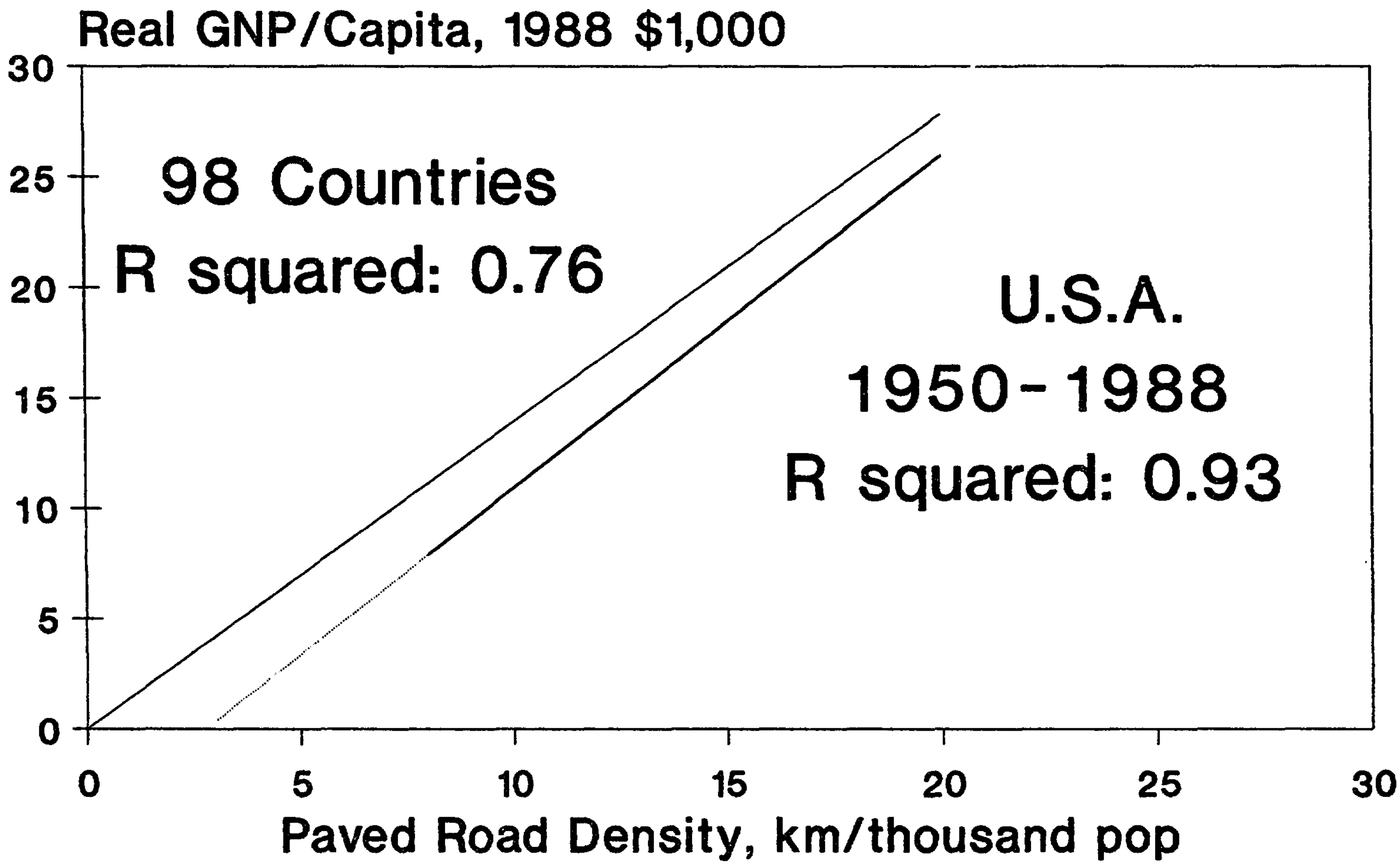

FIGURE 5

Average Road Density in Low, Middle, and High Income Economies

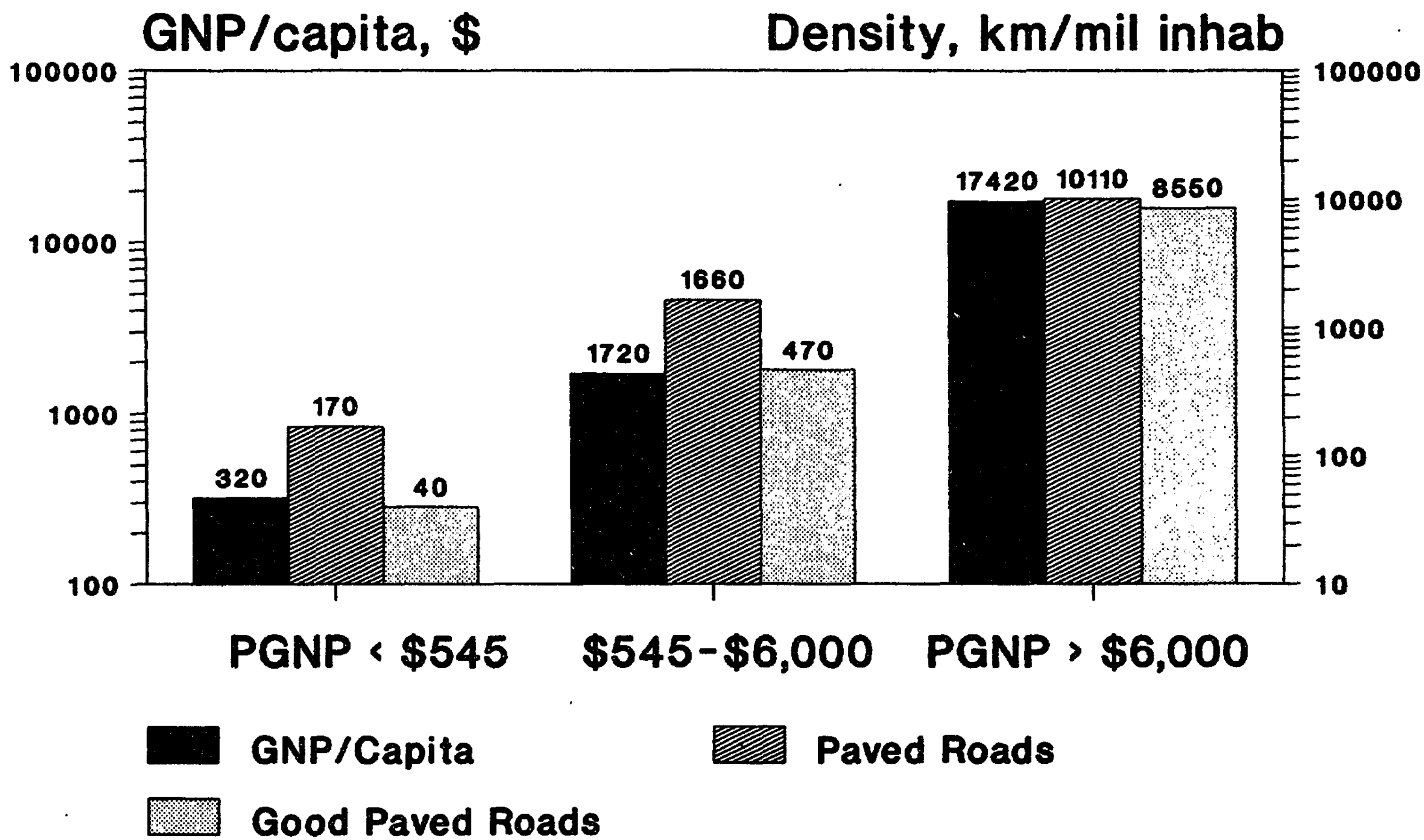

FIGURE 6

GNP and Road Density in Low and Middle Income Economies in Africa

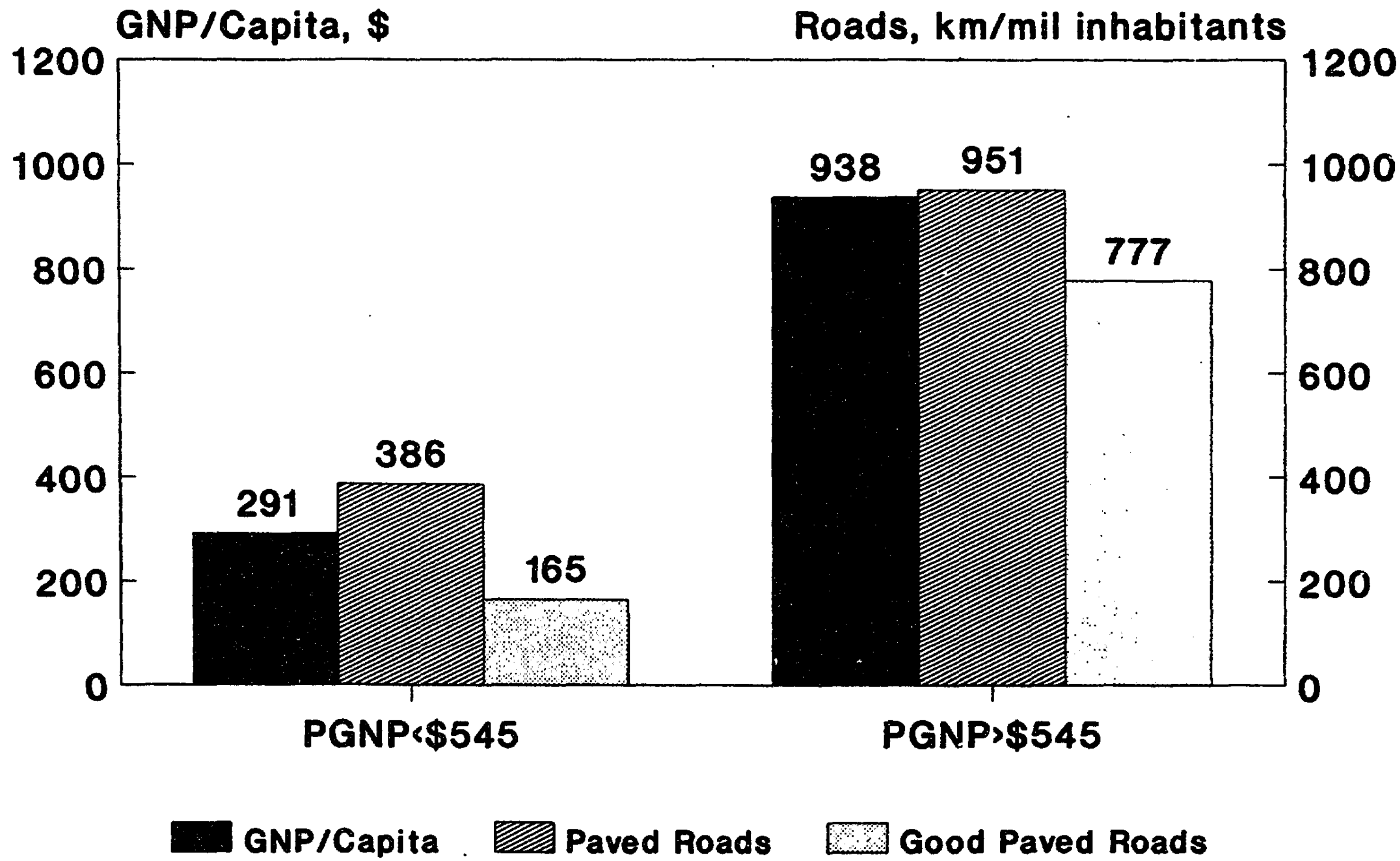

FIGURE 7

Comparison Between Real GNP and Good Paved Road per Million Inhabitants
(1984 and 1989)

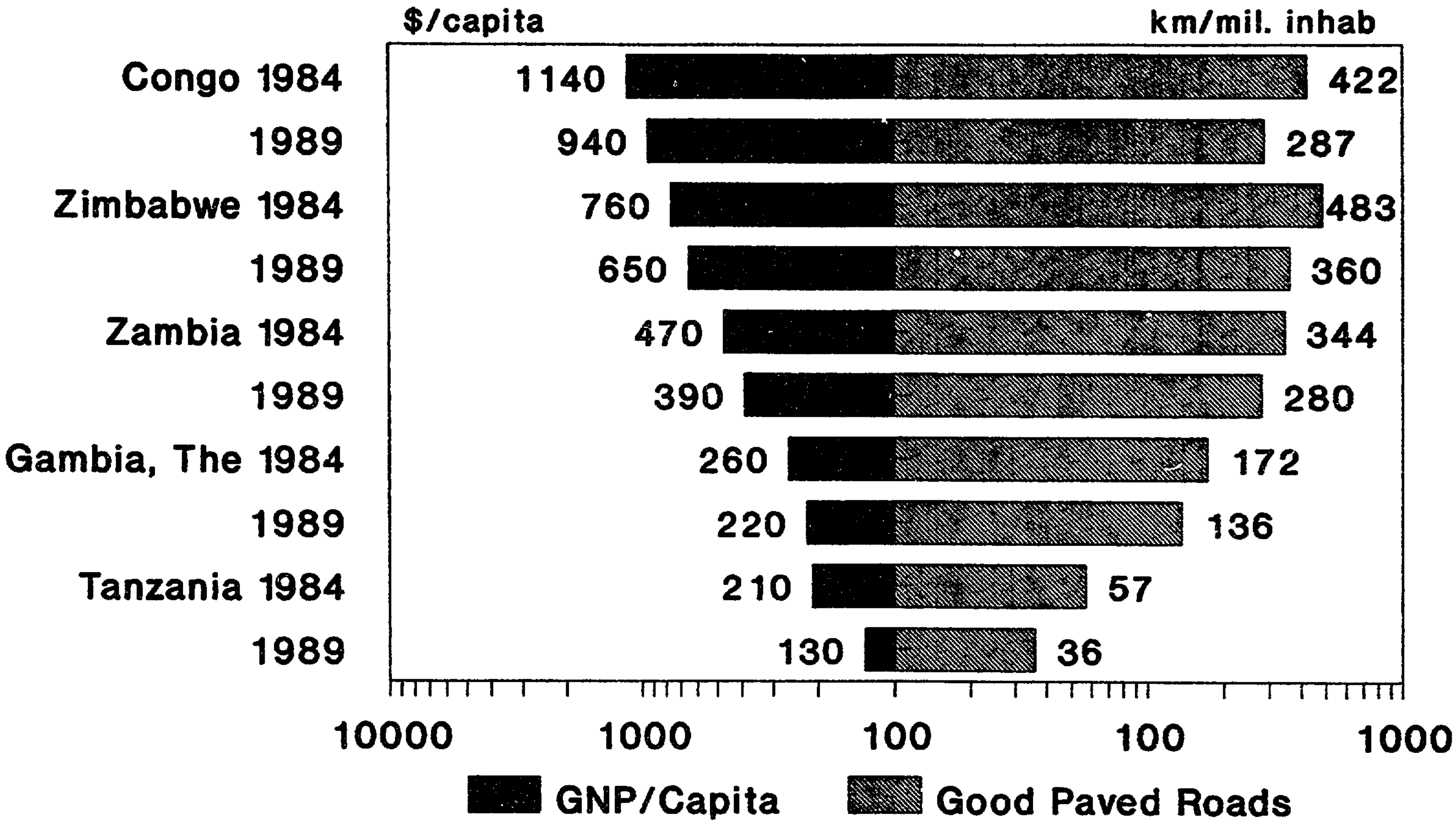

FIGURE 8

Comparison Between Real GNP and Good Paved Roads per Million Inhabitants
(1984 and 1989)

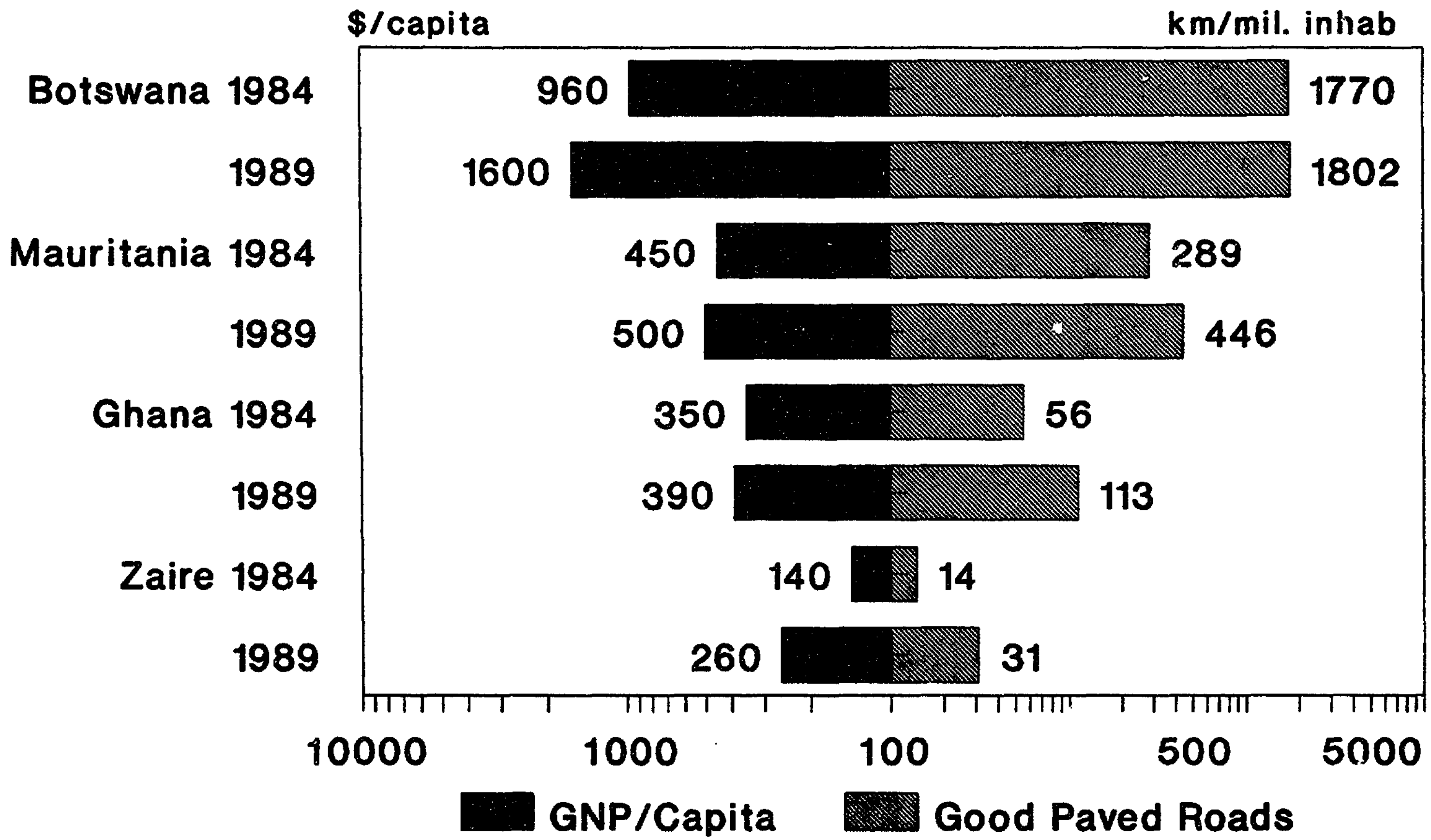

FIGURE 9

Table 1. Summary of Statistical Models Relating Income and Road Infrastructure

Equation	Estimation method	No. of observ.	Constant	X1	X2	X3	X4	X5	R squared	Remarks
1	OLS	98	732.8	0.01	1.67				0.82	World
				(0.03)	(5.38)					
2	OLS	98	0	0.32	1.39				0.81	World
				(1.33)	(4.63)					
3	OLS	98	2.6	1.39					0.76	World
				(20.74)						
4	OLS	98	0	1.39					0.76	World
				(21.06)						
5	OLS	83	564		1.18				0.39	World
					(7.37)					
6	OLS	83	0		1.63				0.18	World
					(10.18)					
7	OLS	39	−3.39	1.24					0.93	USA
				(21.4)						
8	OLS	39	0	0.97					0.88	USA
				(88.18)						
9	OLS	38	−2.9	1.22					0.93	USA lag 1 yr.
				(21.4)						
10	OLS	38	0	0.99					0.89	USA lag 1 yr.
				(92.5)						
11	OLS	37	−2.5	1.2					0.92	USA lag 2 yrs.
				(21.1)						
12	OLS	37	0	1.0					0.90	USA lag 2 yrs.
				(100)						
13	OLS	41	258	0.44					0.14	Africa
				(2.6)						
14	OLS	41	0	0.74					0.03	Africa

Table 1. Summary of Statistical Models Relating Income and Road Infrastructure

Equation	Estimation method	No. of observ.	Constant	X1	X2	X3	X4	X5	R squared	Remarks
				(6.2)						
15	OLS	41	335		0.59				0.16	Africa
					(2.8)					
16	OLS	41	195			0.21			0.23	Africa
						(3.5)				
17	OLS	41	0			0.29			0.17	Africa
						(7.25)				
18	OLS	21	300						0.32	Africa
19	OLS	21	300		0.60				0.38	Africa
					(1.5)					
20	OLS	21	0		66				0.34	Africa
					(.99)					
21	OLS	98	1.3				6.7		0.59	World
							(11.8)			
22	OLS	98	3.7					8.7	0.53	World
								(13.0)		

Notes:
X1 = Paved roads (km/million inhabitants)
X2 = Good Paved roads (km/million inhabitants)
X3 = Unpaved roads (km/million inhabitants)
X4 = Paved Roads (km/'000 sq. km)
X5 = Good Paved Roads (km/'000 sq. km)
OLS = Ordinary Least Square
t statistics in parenthesis

DATA ON POPULATION, GNP/CAPITA, PAVED AND UNPAVED ROADS

			----- PAVED ROAD KM ---- (per million inhabitants)			---- UNPAVED ROAD KM ---- (per million inhabitants)		
Countries	Population (million)	GNP/ Capita	LENGTH (km)	GOOD (km)	FAIR (km)	LENGTH (km)	GOOD (km)	FAIR (km)
Ethiopia	47.4	130	84	40	35	200	94	62
Chad	5.4	150	56	0	6	1,296	n.a.	n.a.
Guinea Bissau	0.9	160	604	236	157	2,324	140	140
Tanzania	24.7	160	146	36	44	794	79	238
Bangladesh	102.1	170	61	9	24	n.a.	n.a.	n.a.
Malawi	8.0	170	276	155	105	930	74	707
Mozambique	14.9	170	343	41	257	574	34	252
Zaire	33.4	170	84	32	19	1,740	765	504
Equa. Guinea	0.4	180	1,118	303	560	1,608	483	675
Myanmar	40.0	180	210	0	105	n.a.	n.a.	n.a.
Nepal	18.0	180	139	56	49	n.a.	n.a.	n.a.
Madagascar	10.9	190	477	267	129	486	131	173
Burkina Faso	8.5	210	177	42	87	851	n.a.	681
Gambia, The	0.8	220	638	140	294	1,000	320	390
Mali	8.0	230	308	194	96	1,230	234	160
Burundi	5.1	240	198	115	50	605	121	345
Uganda	16.2	280	111	11	70	269	0	382
Nigeria	110.1	290	310	208	16	228	n.a.	23
Somalia	5.9	290	467	243	154	788	32	79
Zambia	7.6	290	724	289	217	1,994	598	698
Niger	7.3	300	379	227	87	538	129	156
Sierra Leone	3.9	300	196	122	18	932	75	345
Djibouti	0.4	320	1,030	525	393	1,800	918	685
Rwanda	6.7	320	145	59	85	710	135	328
China	1,088	330	159	16	111	n.a.	n.a.	n.a.
India	816.0	340	150	30	68	n.a.	n.a.	n.a.

DATA ON POPULATION, GNP/CAPITA, PAVED AND UNPAVED ROADS

			PAVED ROAD KM (per million inhabitants)			UNPAVED ROAD KM (per million inhabitants)		
Countries	Population (million)	GNP/ Capita	LENGTH (km)	GOOD (km)	FAIR (km)	LENGTH (km)	GOOD (km)	FAIR (km)
Pakistan	106.3	350	227	41	114	n.a.	n.a.	n.a.
Comoros	0.4	370	1,228	528	650	1,113	278	425
Kenya	22.4	370	280	90	146	1,681	1,109	252
Togo	3.4	370	441	176	97	388	78	39
C.A.R.	2.9	380	152	46	53	3,055	2,078	489
Haiti	6.3	380	96	0	96	177	16	48
Benin	4.4	390	236	61	118	545	60	190
Ghana	14.0	400	429	120	191	602	102	241
Lesotho	1.7	420	355	188	103	1,169	187	666
Sri Lanka	16.6	420	536	54	161	n.a.	n.a.	n.a.
Guinea	5.4	430	241	120	0	1,056	n.a.	n.a.
Indonesia	175.0	440	157	47	47	n.a.	n.a.	n.a.
Liberia	2.4	450	232	197	30	1,412	212	1,059
Mauritania	1.9	480	789	458	237	316	51	104
Sudan	23.8	480	98	26	42	246	49	49
Yemen	10.2	522	951	370	527	n.a.	n.a.	n.a.
Senegal	7.0	650	540	151	173	929	65	195
Zimbabwe	9.3	650	1,370	370	41	2,467	1,234	740
Philippines	53.4	660	266	82	144	n.a.	n.a.	n.a.
Morocco	21.4	670	692	138	305	n.a.	n.a.	n.a.
Honduras	4.2	700	384	192	165	n.a.	n.a.	n.a.
Swaziland	0.7	700	984	344	344	2,954	1,773	1,093
Papua New Guinea	3.4	710	214	73	96	n.a.	n.a.	n.a.
Egypt	45.9	720	329	128	108	n.a.	n.a.	n.a.
Cote d'Ivoire	11.2	770	355	266	89	982	334	638
Thailand	50.0	860	560	280	168	n.a.	n.a.	n.a.

DATA ON POPULATION, GNP/CAPITA, PAVED AND UNPAVED ROADS

			----- PAVED ROAD KM ---- (per million inhabitants)			---- UNPAVED ROAD KM ---- (per million inhabitants)		
Countries	Population (million)	GNP/ Capita	LENGTH (km)	GOOD (km)	FAIR (km)	LENGTH (km)	GOOD (km)	FAIR (km)
Congo	2.1	910	593	297	71	4,550	1,729	1,229
Dominican Rep.	6.1	970	407	212	41	23	3	7
Peru	18.2	1,000	394	95	95	n.a.	n.a.	n.a.
Botswana	1.2	1,010	1,967	1,848	78	4,870	2,192	925
Cameroon	11.2	1,010	290	110	78	2,627	420	1,497
Bolivia	6.2	1,099	218	46	105	1,477	295	532
Belize	0.2	1,150	2,210	707	1,061	8,250	1,320	6,270
Ecuador	9.1	1,150	371	197	71	530	355	116
Jamaica	2.2	1,150	1,984	198	1,448	1,818	n.a.	1,073
Guatemala	7.7	1,160	395	28	198	77	23	14
Costa Rica	2.5	1,190	1,218	268	353	1,522	274	928
Tunisia	7.0	1,270	1,306	718	470	n.a.	n.a.	n.a.
Turkey	53.8	1280	846	n.a.	n.a.	5113	n.a.	n.a.
Colombia	28.4	1,390	339	142	125	563	203	276
Syrian Arab. Rep.	11.6	1680	1971	n.a.	n.a.	524	n.a.	n.a.
Chile	11.8	1,700	813	342	415	1,947	175	1,499
Brazil	132.6	1,720	763	229	320	n.a.	n.a.	n.a.
Mauritius	1.1	1,800	1,509	1,434	75	127	115	6
Poland	37.9	1860	5804	n.a.	n.a.	3711	n.a.	n.a.
Portugal	10.2	1,970	1,755	877	526	n.a.	n.a.	n.a.
Panama	2.1	1,980	1,473	530	796	1,942	117	1,262
Mexico	76.8	2,040	843	716	84	n.a.	n.a.	n.a.
Malaysia	16.9	2110	1923	n.a.	n.a.	451	n.a.	n.a.
Yugoslavia	23.0	2,120	1,593	478	653	n.a.	n.a.	n.a.
Argentina	30.1	2,230	899	315	189	n.a.	n.a.	n.a.
Romania	22.7	2,290	617	426	130	n.a.	n.a.	n.a.

DATA ON POPULATION, GNP/CAPITA, PAVED AND UNPAVED ROADS

Countries	Population (million)	GNP/ Capita	PAVED ROAD KM (per million inhabitants) LENGTH (km)	GOOD (km)	FAIR (km)	UNPAVED ROAD KM (per million inhabitants) LENGTH (km)	GOOD (km)	FAIR (km)
Algeria	23.8	2,360	1,365	546	437	n.a.	n.a.	n.a.
Uruguay	3.1	2,470	2,079	541	1,227	915	421	430
Gabon	1.1	2,970	636	191	191	4,182	1,338	1,255
Venezuela	18.8	3,250	10,063	4,025	3,824	1,301	299	781
Trinidad and Tobago	1.2	3,350	1,733	1,248	329	n.a.	n.a.	n.a.
Cyprus	0.7	3,590	4,197	1,595	1,595	n.a.	n.a.	n.a.
Korea, Rep.	42.0	3,660	236	165	59	n.a.	n.a.	n.a.
Saudi Arabia	14.0	6200	2414	n.a.	n.a.	4111	n.a.	n.a.
Oman	1.1	6,490	2,993	1,975	599	n.a.	n.a.	n.a.
Australia	16.5	12,340	25,745	21,883	3,862	25,951	n.a.	n.a.
United Kingdom	57.1	12,810	6,170	5,244	925	n.a.	n.a.	n.a.
Italy	57.4	13,330	5,259	4,470	789	n.a.	n.a.	n.a.
Belgium	9.9	14,490	12,443	10,577	1,866	518	n.a.	n.a.
Netherlands	14.8	14,520	6,856	5,828	1,028	935	n.a.	n.a.
Austria	7.6	15,470	14,092	11,978	2,114	n.a.	n.a.	n.a.
France	55.9	16,090	14,402	12,242	2,160	n.a.	n.a.	n.a.
Denmark	5.1	18,450	13,856	11,778	2,078	n.a.	n.a.	n.a.
U.S.A.	246.3	19,840	14,172	12,047	2,126	11,135	n.a.	n.a.
Japan	122.6	21,020	6,008	5,107	901	2,999	n.a.	n.a.
Switzerland	6.6	27,500	10,766	9,151	1,615	n.a.	n.a.	n.a.

Sources: World Development Report, Road Deterioration in Developing Countries, International Road Federation, and Staff Appraisal Reports.

DATA ON POPULATION, GNP/CAPITA, AREA, PAVED AND UNPAVED ROADS

Countries	Population (million)	GNP/ Capita	AREA (thou. km2)	PAVED ROAD KM (per thousand square km) LENGTH (km)	GOOD (km)	FAIR (km)	UNPAVED ROAD KM (per thousand square km) LENGTH (km)	GOOD (km)	FAIR (km)
Ethiopia	47.4	130	1,222	3.3	1.5	1.4	7.8	3.7	2.4
Chad	5.4	150	1,285	0.2	0.0	0.0	5.4	n.a.	n.a.
Guinea Bissau	0.9	160	36	15.1	5.9	3.9	58.1	3.5	3.5
Tanzania	24.7	160	945	3.8	1.0	1.1	20.7	2.1	6.2
Bangladesh	102.1	170	144	43.1	6.5	17.3	n.a.	n.a.	n.a.
Malawi	8.0	170	119	18.6	10.4	7.1	62.5	5.0	47.5
Mozambique	14.9	170	802	6.4	0.8	4.8	10.7	0.6	4.7
Zaire	33.4	170	2,345	1.2	0.5	0.3	24.8	10.9	7.2
Equa. Guinea	0.4	180	28	16.0	4.3	8.0	23.0	6.9	9.6
Myanmar	40.0	180	677	12.4	0.0	6.2	n.a.	n.a.	n.a.
Nepal	18.0	180	141	17.7	7.1	6.2	n.a.	n.a.	n.a.
Madagascar	10.9	190	587	8.9	5.0	2.4	9.0	2.4	3.2
Burkina Faso	8.5	210	274	5.5	1.3	2.7	26.4	n.a.	21.1
Gambia, The	0.8	220	11	46.4	10.2	21.4	72.7	23.3	28.4
Mali	8.0	230	1,240	2.0	1.3	0.6	7.9	1.5	1.0
Burundi	5.1	240	28	36.1	20.9	9.0	110.3	22.1	62.9
Uganda	16.2	280	236	7.6	0.8	4.8	18.5	0.0	26.2
Nigeria	110.1	290	924	37.0	24.8	1.8	27.2	n.a.	2.7
Somalia	5.9	290	638	4.3	2.2	1.4	7.3	0.3	0.7
Zambia	7.6	290	753	7.3	2.9	2.2	20.1	6.0	7.0
Niger	7.3	300	1,267	2.2	1.3	0.5	3.1	0.7	0.9
Sierra Leone	3.9	300	72	10.6	6.6	1.0	50.5	4.0	18.7
Djibouti	0.4	320	22	18.7	9.5	7.1	32.7	16.7	12.5
Rwanda	6.7	320	26	37.3	15.3	22.0	182.9	34.9	84.5
China	1,088	330	9,561	18.1	1.8	12.7	n.a.	n.a.	n.a.
India	816.0	340	3,228	38.0	7.6	17.1	n.a.	n.a.	n.a.

DATA ON POPULATION, GNP/CAPITA, AREA, PAVED AND UNPAVED ROADS

Countries	Population (million)	GNP/ Capita	AREA (thou. km2)	PAVED ROAD KM (per thousand square km) LENGTH (km)	GOOD (km)	FAIR (km)	UNPAVED ROAD KM (per thousand square km) LENGTH (km)	GOOD (km)	FAIR (km)
Pakistan	106.3	350	796	30.3	5.5	15.2	n.a.	n.a.	n.a.
Comoros	0.4	370	2	245.5	105.5	130.0	222.5	55.5	85.0
Kenya	22.4	370	583	10.8	3.4	5.6	64.6	42.6	9.7
Togo	3.4	370	57	26.3	10.5	5.8	23.1	4.6	2.3
C.A.R.	2.9	380	623	0.7	0.2	0.2	14.2	9.7	2.3
Haiti	6.3	380	28	21.6	0.0	21.6	39.8	3.6	10.8
Benin	4.4	390	113	9.2	2.4	4.6	21.2	2.3	7.4
Ghana	14.0	400	239	25.1	7.0	11.2	35.3	6.0	14.1
Lesotho	1.7	420	30	20.1	10.7	5.8	66.2	10.6	37.7
Sri Lanka	16.6	420	66	134.8	13.5	40.5	n.a.	n.a.	n.a.
Guinea	5.4	430	246	5.3	2.6	0.0	23.2	n.a.	n.a.
Indonesia	175.0	440	1,905	14.5	4.3	4.3	n.a.	n.a.	n.a.
Liberia	2.4	450	111	5.0	4.3	0.6	30.5	4.6	22.9
Mauritania	1.9	480	1,031	1.5	0.8	0.4	0.6	0.1	0.2
Sudan	23.8	480	2,506	0.9	0.3	0.4	2.3	0.5	0.5
Yemen	10.2	522	625	15.5	6.0	8.6	n.a.	n.a.	n.a.
Senegal	7.0	650	197	19.2	5.4	6.1	33.0	2.3	6.9
Zimbabwe	9.3	650	391	32.6	8.8	1.0	58.7	29.3	17.6
Philippines	53.4	660	300	47.3	14.7	25.5	n.a.	n.a.	n.a.
Morocco	21.4	670	447	33.1	6.6	14.6	n.a.	n.a.	n.a.
Honduras	4.2	700	112	14.4	7.2	6.2	n.a.	n.a.	n.a.
Swaziland	0.7	700	17	40.5	14.2	14.2	121.6	73.0	45.0
Papua New Guinea	3.4	710	463	1.6	0.5	0.7	n.a.	n.a.	n.a.
Egypt	45.9	720	1,001	15.1	5.9	5.0	n.a.	n.a.	n.a.
Cote d'Ivoire	11.2	770	323	12.3	9.2	3.1	34.1	11.6	22.1
Thailand	50.0	860	513	54.6	27.3	16.4	n.a.	n.a.	n.a.

DATA ON POPULATION, GNP/CAPITA, AREA, PAVED AND UNPAVED ROADS

Countries	Population (million)	GNP/ Capita	AREA (thou. km2)	----- PAVED ROAD KM ---- (per thousand square km) LENGTH (km)	GOOD (km)	FAIR (km)	---- UNPAVED ROAD KM ---- (per thousand square km) LENGTH (km)	GOOD (km)	FAIR (km)
Congo	2.1	910	342	3.6	1.8	0.4	27.9	10.6	7.5
Dominican Rep.	6.1	970	49	50.7	26.4	5.1	2.8	0.4	0.8
Peru	18.2	1,000	1,285	5.6	1.3	1.3	n.a.	n.a.	n.a.
Botswana	1.2	1,010	582	4.1	3.8	0.2	10.0	4.5	1.9
Cameroon	11.2	1,010	475	6.8	2.6	1.8	61.9	9.9	35.3
Bolivia	6.2	1,099	1,099	1.2	0.3	0.6	8.3	1.7	3.0
Belize	0.2	1,150	23	19.2	6.1	9.2	71.7	11.5	54.5
Ecuador	9.1	1,150	284	11.9	6.3	2.3	17.0	11.4	3.7
Jamaica	2.2	1,150	11	396.8	39.7	289.7	363.6	n.a.	214.5
Guatemala	7.7	1,160	109	27.9	2.0	14.0	5.5	1.6	1.0
Costa Rica	2.5	1,190	51	59.7	13.1	17.3	74.6	13.4	45.5
Tunisia	7.0	1,270	164	55.7	30.7	20.1	n.a.	n.a.	n.a.
Turkey	53.8	1,280	767	59.3	n.a.	n.a.	360.0	n.a.	n.a.
Colombia	28.4	1,390	1,139	8.4	3.5	3.1	14.0	5.1	6.9
Syrian Arab. Rep.	11.6	1,680	185	123.6	n.a.	n.a.	32.9	n.a.	n.a.
Chile	11.8	1,700	757	12.7	5.3	6.5	30.4	2.7	23.4
Brazil	132.6	1,720	8,512	11.9	3.6	5.0	n.a.	n.a.	n.a.
Mauritius	1.1	1,800	2	830.0	788.5	41.5	70.0	63.0	3.5
Poland	37.9	1,860	313	702.8	n.a.	n.a.	449.4	n.a.	n.a.
Portugal	10.2	1,970	92	194.6	97.3	58.4	n.a.	n.a.	n.a.
Panama	2.1	1,980	77	40.2	14.5	21.7	53.0	3.2	34.4
Mexico	76.8	2,040	1,958	33.1	28.1	3.3	n.a.	n.a.	n.a.
Malaysia	16.9	2,110	330	98.5	n.a.	n.a.	23.1	n.a.	n.a.
Yugoslavia	23.0	2,120	256	143.1	42.9	58.7	n.a.	n.a.	n.a.
Argentina	30.1	2,230	2,767	9.8	3.4	2.1	n.a.	n.a.	n.a.
Romania	22.7	2,290	238	58.8	40.6	12.4	n.a.	n.a.	n.a.

DATA ON POPULATION, GNP/CAPITA, AREA, PAVED AND UNPAVED ROADS

Countries	Population (million)	GNP/ Capita	AREA (thou. km2)	PAVED ROAD KM (per thousand square km) LENGTH (km)	GOOD (km)	FAIR (km)	UNPAVED ROAD KM (per thousand square km) LENGTH (km)	GOOD (km)	FAIR (km)
Algeria	23.8	2,360	2,328	14.0	5.6	4.5	n.a.	n.a.	n.a.
Uruguay	3.1	2,470	177	36.4	9.5	21.5	16.0	7.4	7.5
Gabon	1.1	2,970	268	2.6	0.8	0.8	17.2	5.5	5.1
Venezuela	18.8	3,250	912	207.4	83.0	78.8	26.8	6.2	16.1
Trinidad and Tobago	1.2	3,350	5	416.0	299.6	79.0	n.a.	n.a.	n.a.
Cyprus	0.7	3,590	9	326.4	124.0	124.0	n.a.	n.a.	n.a.
Korea, Rep.	42.0	3,660	99	100.3	70.2	25.1	n.a.	n.a.	n.a.
Saudi Arabia	14.0	6,200	2,331	14.5	n.a.	n.a.	24.7	n.a.	n.a.
Oman	1.1	6,490	212	15.5	10.2	3.1	n.a.	n.a.	n.a.
Australia	16.5	12,340	7,700	55.2	46.9	8.3	55.6	n.a.	n.a.
United Kingdom	57.1	12,810	244	1443.8	1227.2	216.6	n.a.	n.a.	n.a.
Italy	57.4	13,330	301	1002.8	852.4	150.4	n.a.	n.a.	n.a.
Belgium	9.9	14,490	31	3973.7	3377.7	596.1	165.6	n.a.	n.a.
Netherlands	14.8	14,520	41	2446.6	2079.6	367.0	333.6	n.a.	n.a.
Austria	7.6	15,470	84	1275.0	1083.7	191.3	n.a.	n.a.	n.a.
France	55.9	16,090	552	1458.5	1239.7	218.8	n.a.	n.a.	n.a.
Denmark	5.1	18,450	431	164.0	139.4	24.6	n.a.	n.a.	n.a.
U.S.A.	246.3	19,840	9,373	372.4	316.6	55.9	292.6	n.a.	n.a.
Japan	122.6	21,020	378	1948.6	1656.3	292.3	972.8	n.a.	n.a.
Switzerland	6.6	27,500	413	172.0	146.2	25.8	n.a.	n.a.	n.a.

Sources: World Development Report, Road Deterioration in Developing Countries, International Road Federation, and Staff Appraisal Reports.

TIME SERIES DATA FOR USA 1950 TO 1988

Year	Popn. in m	GNP/Capita 1982 dollars	Paved Rd/ mil. inhab	Paved Rd/ thou. km2
1950	152.3	7,903	8,240	134
1951	154.9	8,168	8,455	140
1952	157.6	8,270	8,729	147
1953	160.1	8,524	9,236	158
1954	163.0	8,280	9,417	164
1955	165.9	8,942	9,660	171
1956	168.9	9,128	9,926	179
1957	172.0	9,130	10,150	186
1958	174.9	8,730	10,469	195
1959	177.8	9,304	10,760	204
1960	180.7	9,402	10,952	211
1961	183.7	9,431	11,150	219
1962	186.5	9,854	11,345	226
1963	189.2	10,076	11,625	235
1964	191.9	10,447	11,797	242
1965	194.3	11,160	12,049	250
1966	196.6	11,748	12,113	254
1967	198.7	11,952	12,308	261
1968	200.7	12,392	12,619	270
1969	202.7	12,511	12,843	278
1970	205.1	12,263	13,007	285
1971	207.7	12,525	13,131	291
1972	209.9	13,339	13,323	298
1973	211.9	13,884	13,372	302
1974	213.9	13,403	13,675	312
1975	216.0	13,159	13,818	318
1976	218.0	13,717	13,927	324
1977	220.2	14,228	14,395	338
1978	222.6	14,646	14,529	345
1979	225.1	14,523	14,196	341
1980	227.8	14,043	14,409	350
1981	230.1	14,020	14,475	355
1982	232.5	13,617	13,910	345
1983	234.8	13,966	13,774	345
1984	237.0	14,774	14,529	367
1985	239.3	15,122	14,187	362
1986	241.6	15,389	14,345	370
1987	243.9	15,800	14,342	373
1988	246.3	16,339	14,326	376

Source:
a) Highway Statistics, DOT
b) Statistical Abstracts

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