National Economic Development and Prosperity Related to Paved Road Infrastructure

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The relationships between the extent and quality of paved road infrastructure and national per capita income are investigated. A number of selected variables are incorporated in the relationship involving a study of 98 countries. The analyses include cross-sectional and time series methods, with data going back to 1950. Consistent and significant associations between economic development, in terms of per capita gross national product, and paved road infrastructure, on a per capita basis, are demonstrated. The data show that the per capita stock of paved road infrastructure in high-income national economies is dramatically greater than those in middle- and low-income economies. For example, the average density of paved roads (km/1 million people) varies from 170 in low-income economies to 1,660 in middle-income economies to 10,110 in high-income economies. In other words the average density of paved roads in high-income economies is nearly 60 times that in low-income economies. Although it is less definitive, road condition also appears to be associated with economic development. The average density of paved roads in good condition ranges from 40 km/1 million people in low-income economies to 470 in middle-income economies to 8,550 in high-income economies. The information and relationships presented can be used as indicators of weakness or strength in national road infrastructure stock or asset. An initial analysis of Canada's relative ranking is provided. Causality (that is, does an increase in road stock lead to growth, or vice versa?) is also briefly explored.

Contemporary news often hints at the way a country's economy relates to its road and transport infrastructure. During the Gulf War in 1991, the allies, in a quest to neutralize Iraq, concentrated their fire on the destruction of the country's road and bridge network with an intensity second only to that against Iraq's military targets. More recently, countries such as the United States, Canada, and Australia, in their bid to revitalize their economies, have announced stimulus packages with significant components devoted to reconstruction and repair of their road networks.

Restriction of accessibility limits efficient 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.

In developing countries road transport plays an essential role in marketing agricultural products and providing access to health, education, and agricultural inputs and extension services by providing about 80 to 90 percent of the total inland and border crossing transport of people and goods. A World Bank long-term perspective study (*1*) 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.

The impact of road transportation in developed regions is also significant. As an example, in the United States it accounts for 15 percent of the gross national product (GNP) and 84 percent of all spending on transportation (*2*). 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 that can be used as indicators of areas of weaknesses or strengths in a country's road infrastructure stock. It is based on correlations or direct comparisons of selected variables on existing road networks and on national output. As pointed out by Owen (*3*), 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. An initial analysis of Canada's relative ranking is provided. Causality (that is, does an increase in road stock lead to growth, or vice versa?) is also briefly explored.

CROSS-COUNTRY COMPARISON OF ROADS AND DEVELOPMENT

Recent analyses have been carried out to explore the empirical linkage between road infrastructure and economic development; those analyses have used per capita GNP as the dependent variable and selected indicators of magnitude and condition of road networks as independent variables (*4*). Some key variables are defined in the following paragraphs.

GNP is the measurement of the total market value of the final goods and services produced in a nation's economy during a given time period, normally 1 year. GNP per capita is a country's GNP divided by its population, henceforth denoted 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 in the World Bank policy paper on road deterioration (*5*) as (a) good, meaning that paved roads are substantially free of defects and require only routine maintenance or unpaved roads need only routine grading and spot repairs; (b) fair, meaning that paved roads have significant defects and require resurfacing or strengthening or that unpaved roads need reshaping or resurfacing (regraveling) and spot repair of drainage; and (c) poor, meaning that paved roads have extensive defects and require im-

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mediate rehabilitation or reconstruction or that unpaved roads need reconstruction and major drainage works.

Using existing data from 98 developing and developed countries, Queiroz and Gautam (*4*) developed the following significant relationship between PGNP and density of paved roads:

$$PGNP = 1.39 \times LPR$$

where PGNP is per capita GNP ($/inhabitant) and LPR is the per capita length (or density) of paved roads (km/1 million inhabitants). The coefficient of determination (R^2) is 0.76, the number of degrees of freedom is 97, and the t-statistic of the coefficient is 20.7. The y-intercept term was not found to be significant at the 0.01 level of significance; consequently, it was not included in the equation and the R^2 value was appropriately adjusted. The scatter diagram and the derived relationship are shown in Figure 1.

For comparison purposes an analysis was also carried out by using the spatial density of roads as an independent variable. A slightly less significant regression equation (with an R^2 value of 0.50) was obtained between PGNP and the spatial density of paved roads:

$$LGNP = 2.25 + 0.49 \times LD$$

where LGNP is the decimal logarithm of PGNP ($/inhabitant), and LD is the logarithm of density of the paved roads (km/1,000 km^2 of land area).

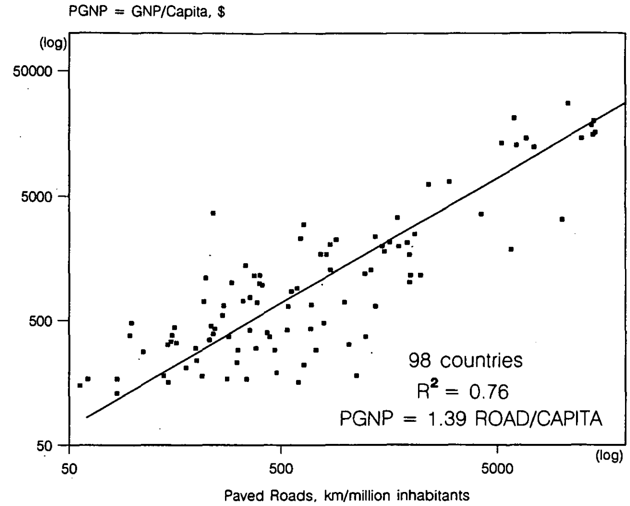


FIGURE 1 Relationship between GNP and paved road density per capita.

COMPARISON OF TIME SERIES DATA IN UNITED STATES AND CANADA

A vast amount of historic data is available on the road network and economy of the United States (*6,7*). By carrying out a time series analysis of U.S. data from 1950 to 1988, Queiroz and Gautam (*4*) found a significant positive relationship between PGNP (in $1,000/inhabitant, using 1982 constant dollars) and LPR (in km/1,000 inhabitants):

$$PGNP = -3.39 + 1.24 \times LPR$$

with an R^2 value of 0.93; the number of degrees of freedom is 37, and the t-statistic of the coefficient is 21.4 (Figure 2). The intercept (i.e., −3.4) in the previous 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^2 of 0.88. However, the 0.97 coefficient in the latter equation would be biased (because the y-intercept is significant). Therefore, the equation with the −3.39 intercept is preferred.

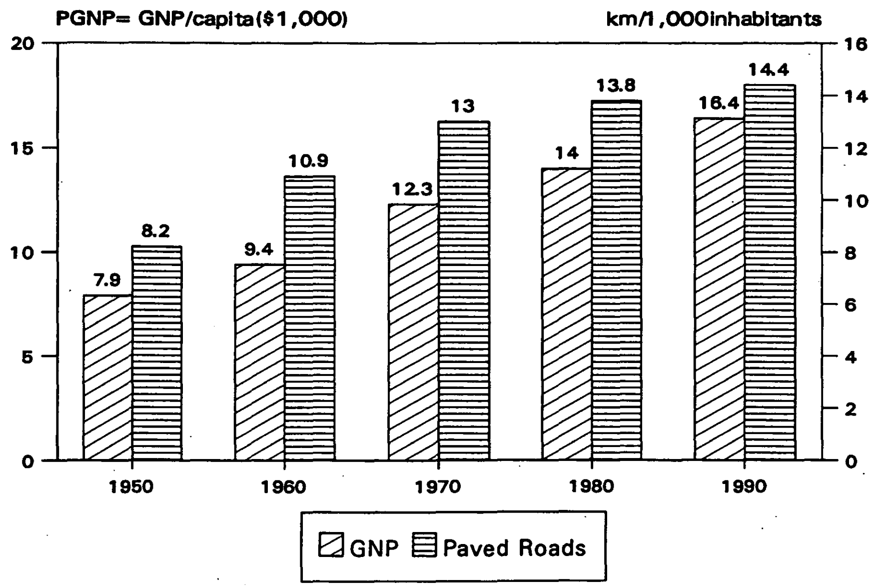


FIGURE 2 Evolution of GNP per capita and paved road density per 1,000 capita in the United States.

An interesting situation exists in running regressions between PGNP and LPR by using different time lags: the highest correlation existed when PGNP for a given year was associated with LPR 4 years earlier (*4*). This appears to indicate that paved roads had an effect on GNP, but there was a time lag of about 4 years between construction and ultimate impact. This 4-year time lag is in broad agreement with the "half a decade" lag period observed by Aschauer (*8*). 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 United States.

That result was obtained for the United States. Now similar data available for Canada are examined. Reasonable data are available in terms of GNP and LPR (*9*). Data for GNP are not so readily available on a consistent basis for the number of years covered in Figure 2. However, the use of several sources plus a number of assumptions made it possible to develop Canadian GNP data for the period 1950 to 1988 (details are available from the authors). The following significant positive relationship between PGNP (in $1,000/inhabitant, using 1988 constant U.S. dollars) and LPR (in km/1,000 inhabitants) was found:

$$PGNP = 0.85 + 1.33 \times LPR$$

with an R^2 value of 0.88; the number of degrees of freedom is 37, and the t-statistic of the coefficient is 16.42.

Like the United States, Canada has the same evolutionary trend between GNP and paved road infrastructure (Figure 3). The 4-year time lag between road paving and economic advance also appears to exist in Canada.

More detailed time series analyses are suggested for future considerations. This could include, inter alia, two-stage least squares tests for causality (e.g., the Granger test) and analyses of data from other countries.

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, that is, a factor of 1.213 (*7*). The resulting equation is

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

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

The inference spaces for both equations can be approximately defined by (a) cross-sectional analysis, with an LPR between 60 and 20,000 km/1 million population, and (b) time series analysis, with an LPR between 8,000 and 20,000 km/1 million population. Figure 4 shows the two equations according to their inference spaces. As can be seen in Figure 4, there is relatively good consistency between both equations.

The equation resulting from the time series analysis for Canada (1950 to 1988) is

$$PGNP_{88} = 0.86 + 1.33 \times LPR$$

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

The time series line for Canada is merged in Figure 4. It indicates a very good agreement with the relationship for the 98 countries but some offsets with the U.S. relationship. In other words for any given PGNP value the United States has a greater paved road density, currently about 13 percent greater. One can speculate on the reasons, which may include, for example, greater efficiency of economies of

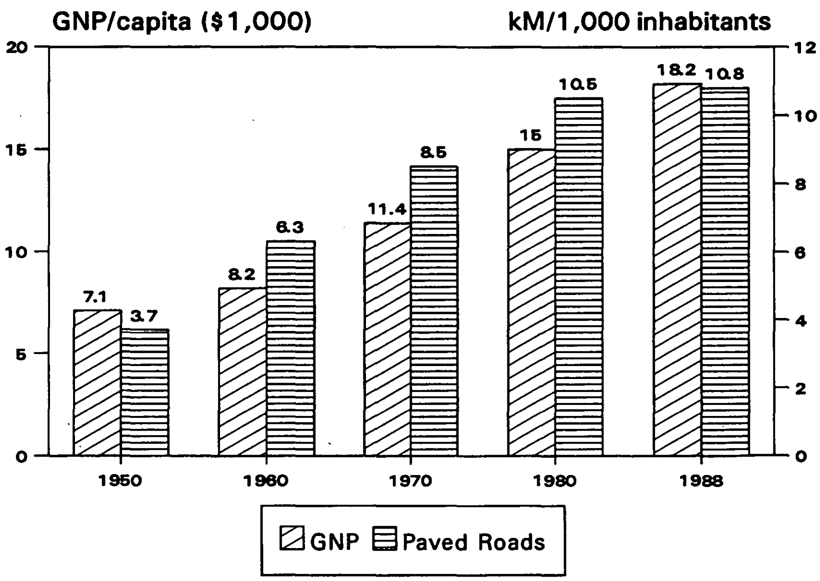


FIGURE 3 Evolution of GNP and paved road infrastructure in Canada.

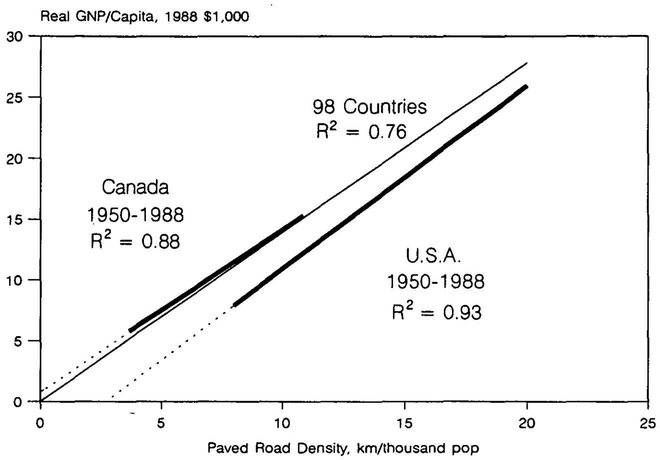


FIGURE 4 Comparison between cross-sectional and time series analyses.

scale. This could be supported by the fact that the United States annually has twice the hot mix paving tonnage of all of Europe combined.

COMPARISON OF ROAD SUPPLY IN WORLD ECONOMIES

A comparison between the supplies and conditions of paved road networks in 98 developing and developed countries is shown in Figure 5. The country groups in Figure 5 are defined as follows (*10*):

1. Low-income economies are those with a PGNP of $545 or less in 1988,
2. Middle-income economies are those with a PGNP of more than $545 but less than $6,000 in 1988, and
3. High-income economies are those with a PGNP of $6,000 or more in 1988.

The 98 countries summarized in Figure 5 comprised (a) 42 low-income economies (average PGNP of $320), (b) 43 middle-income economies (average PGNP of $1,720, and (c) 13 high-income economies (average PGNP of $17,420).

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

These results appear to indicate that economic development has a link with paved road density and also to the maintenance standards of those roads. A similar trend probably exists for unpaved roads, because 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 past 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 blacktop, effectively resulting in a decrease in a country's paved road network. Although many other factors are involved, several countries in which PGNP has de-

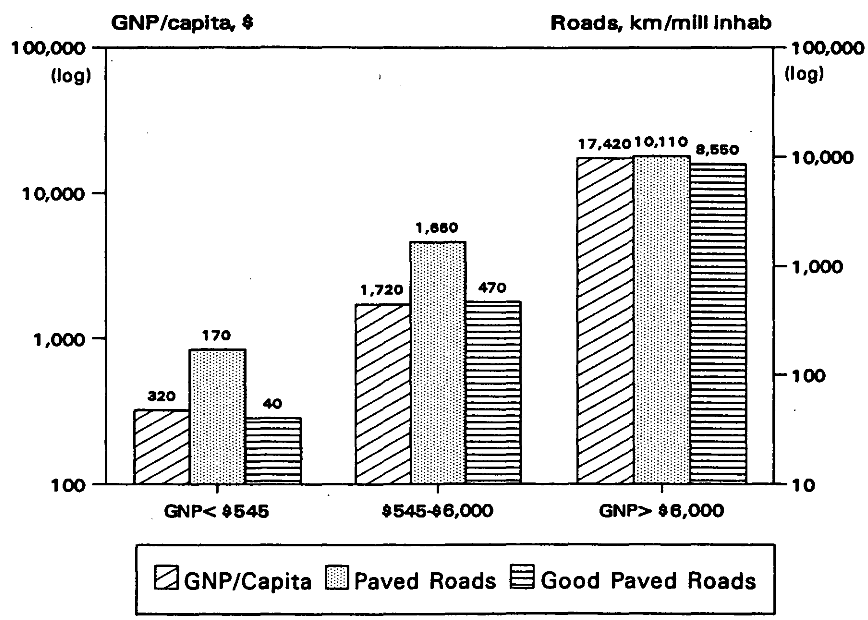


FIGURE 5 Road infrastructure in low-, middle-, and high-income countries.

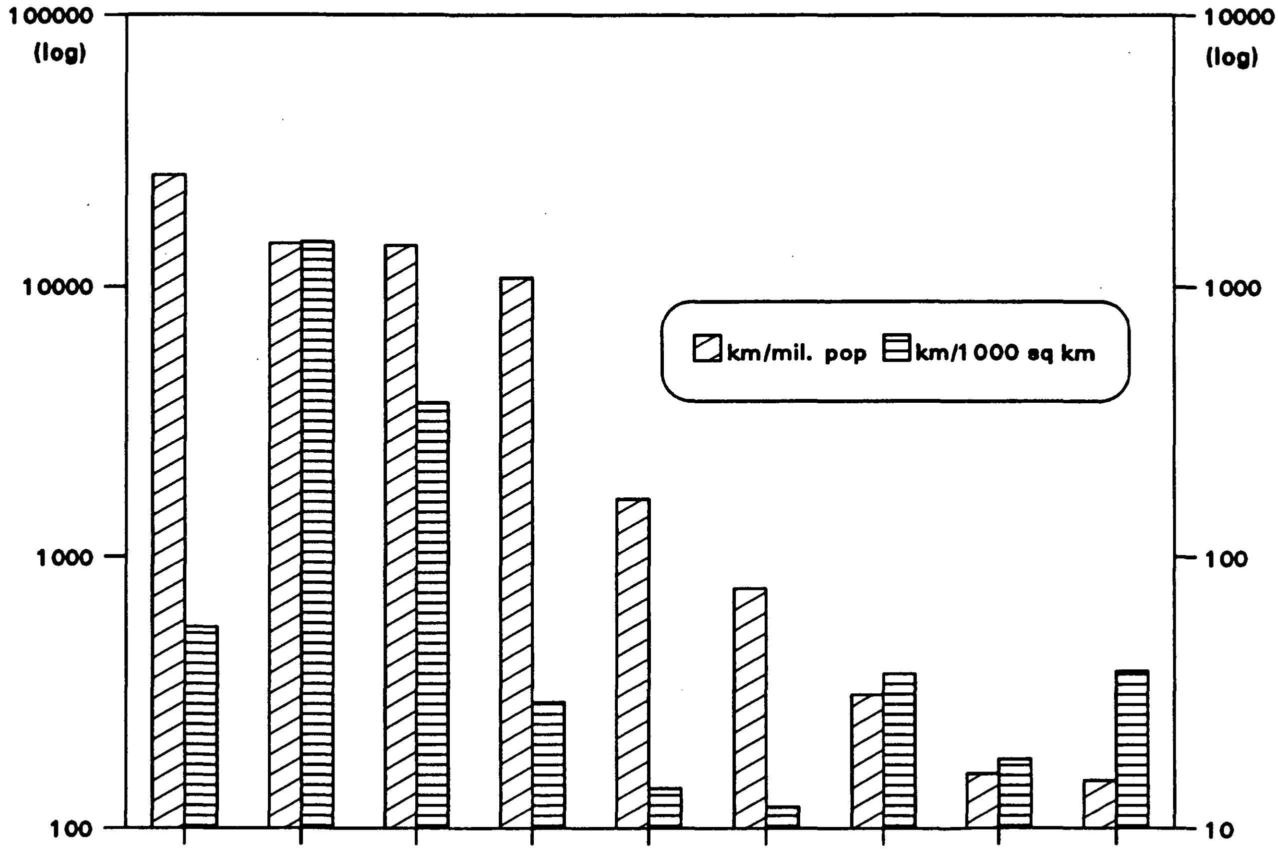
creased in recent years have also faced significant deterioration in their road networks.

For illustrative purposes a comparison of paved road density (km/1 million population) and spatial density (km/1,000 km^2 of land area) in nine large countries is given in Figure 6. As shown in Figure 6 there is a wide range in density, from 25,745 km/1 million population in Australia (labeled Austra in Figure 6) to 1,630 km/1 million population in Russia to 150 km/1 million population in India. Canada is one of the nine countries included in Figure 6 for comparative purposes (*11*). The two types of densities for Canada are similar to those for Australia. This is logical because the two countries are also reasonably similar in terms of size, population, and economy.

DISCUSSION OF CAUSALITY

Assessing the impact of road infrastructure on economic performance is not straightforward because many other factors are involved, and the direction of causation between changes in income and changes in road infrastructure is not clear-cut. One could argue that causation in the equations previously shown could run in either direction. Causality is an issue highlighted for future research. Notwithstanding the controversy over cross-country studies of growth described by Levine and Renelt (*12*), there appears to be a consensus in 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 (*3*). The following examples further illustrate the linkage between road infrastructure and development:

1. Chhibber (*13*) and Binswanger (*14*) found that the lack of roads is a significant constraint on the supply response of agriculture.
2. Shah (*15*) 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.
3. 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. Analyzing U.S. data 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 United States.



	Austra	France	USA	Canada	Russia	Brazil	Nigeria	China	India
km/mil. pop	25745	14402	14172	10755	1630	763	310	159	150
km/1 000 sq km	55	1459	372	29	14	12	37	18	38

FIGURE 6 Paved road density in selected countries.

4. Easterly and Rebelo (*17*) found that investment in transport and communication is consistently correlated with growth with a coefficient that implies a high return to public investment.

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 outcomes of infrastructure investments carried out by Kauffman (*18*) 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 et al. (*19*). 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 (*19*).

CONCLUSIONS

The data discussed 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. and Canadian data between 1950 and 1988 showed significant relationships between PGNP, or per capita gross domestic product in the case of Canada, and density (i.e., LPR) of paved road network. Moreover, there is relatively good consistency between the regression equations from cross-section and time series analyses when they are compared according to their respective inference spaces. Because of the high degree of correlation between the densities of paved and unpaved roads, LPR should be interpreted as a proxy for a country's road stock, paved and unpaved.

The per capita stock of road infrastructure in high-income economies is dramatically greater than those in middle- and low-income economies. For instance, the average density of paved roads (km/1 million inhabitants) varies from 170 in low-income economies to 1,660 (plus 876 percent) in middle-income economies and 10,110 in high-income economies, the latter 5,800 percent higher than that in the low-income economies. Road condition also appears to be associated with economic development: the average density of paved roads in good condition (km/1 million inhabitants) varies from 40 in low-income economies to 470 in middle-income economies and 8,550 in high-income economies.

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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