

Road infrastructure development and economic growth

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Abstract. Stimulating economic growth and development of road infrastructure in economical lagging regions is the goal of many countries. This is because road infrastructure plays a crucial role by providing mobility for the efficient movements of people and goods, as well as providing accessibility to a wide variety of commercial and social activities. However, to achieve a sustainable economic growth, focusing on road infrastructure development alone would not be sufficient. Thus, this study analyse the contribution of road infrastructure development and other socio-economic factors that contributed to economic growth. To shed light on this issue, fixed-effects panel linear regression analysis was conducted using time-series cross-sectional data for 60 countries over the period of 3 decades from 1980 to 2010. The key finding of this study demonstrated that the growth in road length per thousand population, per capita export, per capita education expenditure and physical capital stock per worker contributed positively to economic growth. It was observed that there is an inverted U-shaped dependency relationship between urbanization and economic growth. That is, the economic growth increases at low urbanization levels but decreases once urbanization exceeds a threshold level. Moreover, it was also observed that the growth in road length per thousand population would facilitate export growth. In summary, this study suggest that policies focused on road infrastructure development should be implemented hand-in hand with other socio-economic and urban growth policies, in order to realize a sustainable economic growth.

1. Introduction

A breadth of research [1-6] revealed that the road infrastructure development were positively associated with economic growth. Generally, road infrastructure plays a crucial role by providing mobility for the efficient movements of people, goods and services as well as providing accessibility to land and a wide variety of commercial and social activities [7]. The provision of road infrastructure not only lower the physical barrier by stimulating the movements of people, goods [8] and services but also improve access to markets, social services and employment by reducing the overall transportation times and costs. The development or provision of high mobility road infrastructure such as expressway can increase the speed and improve the efficiency of domestic and international trades by reducing the transportation times and costs; whilst the development or provision of high accessibility road infrastructure such as local road allow easy land access and promote commercial and social activities at local level [9-10].



Empirical studies and scientific evidence show that the investment in paved roads, especially in countries with shortages of road infrastructure have been proven to provide an impressive return in economy [1]. In Sri Lanka, the investment in highway infrastructure has led to increases in the industries' output by more than 60% [2]. The road construction in China, especially rural roads has raised the country's national gross domestic product (GDP) four times higher than high-grade roads due to greater benefits than costs on the investments of rural roads [3]. Similarly, improvements in urban roads and major regional roads had increased the GDP share for both manufacturing and service industry in China [4]. Nevertheless, several scientific evidence showed that the growth of road infrastructure has no significant impact on economic growth [11-12]. For example, the improvements in highway infrastructure in the North Carolina counties in the United States between 1985 to 1997 has no significant impact on employment growth [11] and improvements in paved roads and highways in China from 1986 to 2003 has no significant effect on per capita GDP growth [12].

As shown above, the evidence on the role of road infrastructure development in economic growth is indecisive. However, historical development of road infrastructure indicated that countries that are more affluent generally have better road infrastructure, thus promoting agriculture, trade, industry and commerce, thereby helping these countries to sustain higher economic growth. In contrast, impoverished countries generally lack of road infrastructure and agriculture is the main economic source of income for most of the population, thus, their economic growth is limited. An efficient road infrastructure or a good road network created a competitive edge in moving goods economically. Conversely, lack of road infrastructure or poor road network systems are barriers to agriculture, industry and trade, and may hinder the process of urbanization and socioeconomic development. In view of this, this study intended to investigate the role of road infrastructure development on economic growth by utilizing a larger sample size with longer time period. Apart from this, empirical research also demonstrated that the positive effect of road infrastructure development on economic growth declines if the development of roads is increased in isolation from other socioeconomic development factors such as physical capital, human capital, health and education [1, 13]. Thus, the second objective of this study was to determine the effect of other socioeconomic factors (exports, education, physical capital stock and urbanization) that contributed to economic growth.

The rest of the paper was organized as follows. First, in Section 2, the literature of the socioeconomic factors on economic growth was discussed. Following this, in Section 3, the data and variables use in the study was described. Then, in Section 4, the methodology used to estimate the economic growth was discussed. Next, in Section 5, results and discussions were presented. Finally, the conclusion of the study, policy implications, limitations and the directions of the future research was discussed in Section 6.

2. Literature Review

The Solow growth model indicated that the human capital stock and the physical capital play a significant role in economic growth [14-16]. The human capital stock refers to the level of education and the life-long learning or the earning ability in the labour force, which contributed directly and indirectly, to economic growth. Empirical scientific evidence suggested that the investment in education is essential in accumulating human capital required to facilitate and sustain higher economic growth [17-18].

The physical capital stock is a measure of non-residential capital stock per worker and it is an integral component of economic growth. It is defined as the stock of capital goods, such as machines, equipment and technology required for production. It could not be measured directly but it can be estimated using the perpetual inventory method [19-22].

Economy theory shows that economic impulse based on expansion of domestic market is bound to be exhausted quickly. However, economic driven by export market promote a positive long run effects on economic growth [23-29]. This is because export market has no growth restriction on the demand for goods [29-32] and export expansion could increase the total factor productivity [30, 33].

Inevitably, development in road infrastructure would facilitate the export growth and consequently enhance the economic growth.

Urbanization refers to a transition process, in which, people move from rural to urban areas, which can have profound impacts on development and it is an inherent part of economic growth [34-36]. This is because urban areas provide higher economic opportunity and other opportunity such as education centre, health care services and credit facilities. The urbanization and economic growth theory is supported by Kuznets, where the population migration from rural to urban areas, is afforded by population growth and structural changes that generate productivity and wage gains per worker and the per capita income increase is associated with economic growth [37]. Scientific evidence also showed that there is an inverted U-shaped dependency relationship between urbanization and economic growth [38-40] that is economic growth increases at low urbanization levels but decreases once urbanization exceeds a threshold level.

In view of this, this paper attempted to investigate how road infrastructure development and other socioeconomic factors (export, education, physical capital stock and urbanization) facilitates economic growth.

3. Data and Variables

This section describes the data and variables used in this study. All data and variables used were secondary data obtained from various sources, such as the World Development Indicator (WDI) and Education Statistics (ED) from World Bank, Penn World Table 7.1 (PWT 7.1) and International Road Federations (IRF). The data used were annual observations on 'purchasing power parity converted gross domestic products (GDP) per capita (chain series) at 2005 constant price' or 'rgdpch', 'road length per thousand population' or 'roadpp', 'per capita exports of goods and services' or 'exp', 'per capita government expenditure on education' or 'edu', 'physical capital stock per worker' or 'kpw' and 'ratio of urban population to rural population' or 'urb' of 60 countries over a period of three decades from 1980 to 2010. The description of variables and data sources were given in Table 1.

Table 1. Description of variables and data sources.

Variable	Definition	Data Sources
rgdpch	Purchasing power parity converted gross domestic products per capita (chain series) at 2005 constant prices	PWT 7.1
roadpp	Road length per thousand population	IRF, WDI
exp	Per capita export of goods and services	WDI, PWT 7.1
edu	Per capita government expenditure on education	ES, WDI, PWT 7.1
kpw	Physical capital stock per worker	PWT 7.1, WDI
urb	Ratio of urban population to total population	WDI

The total sample used in the panel linear regression analysis was 1174. The data in each country has at least a minimum of 5 years observations. The list of countries included in this study was stated in Table 2.

The dependent variable in this study was the 'purchasing power parity converted gross domestic products per capita (chain series) at 2005 constant prices' or 'rgdpch'. This data was obtained from PWT 7.1 and was utilized as a proxy to describe the economic growth of a country.

The independent variable - the 'road length per thousand population' or 'roadpp', was derived by dividing the total length of roads by thousand population for a particular country in a particular year. The road length data was obtained from the World Road Statistic annual yearbooks published by the IRF while the population data was taken from WDI. The 'roadpp' variable was used as a proxy to describe the road infrastructure development of a country.

Other independent variables, such as 'per capita exports of goods and services' or 'exp', was derived by multiplying exports of goods and services as percent of GDP drawn from WDI with 'rgdpch' taken from PWT 7.1. The 'exp' was used as a proxy to describe the countries' export level.

The 'per capita government expenditure on education' or 'edu' was used as a proxy for describing human capital as indicated in the Solow growth model. This variable was computed by multiplying government expenditure on education as percent of GDP with 'rgdpch'. The per capita government expenditure on education was drawn from ES and WDI.

Data required to estimate the 'physical capital stock per worker' or 'kpw' was taken from PWT 7.1 and WDI. It was computed following the perpetual inventory method [19-22]. This data was transformed to natural log prior to the panel regression analysis to improve the interpretation and to reduce the heteroskedasticity in the data.

The urbanization ratio variable was used as a proxy to describe the urbanization level of a country. It was computed by dividing the total urban population by the total rural population. Population data was obtained from WDI.

Table 2. List of countries.

No.	Country	No.	Country	No.	Country
1	Argentina	21	Georgia	41	Netherlands
2	Austria	22	Germany	42	Norway
3	Azerbaijan	23	Greece	43	Pakistan
4	Bangladesh	24	Hungary	44	Panama
5	Belgium	25	India	45	Peru
6	Bolivia	26	Indonesia	46	Philippines
7	Botswana	27	Iran	47	Poland
8	Bulgaria	28	Ireland	48	Romania
9	Canada	29	Israel	49	Slovak Republic
10	Chile	30	Italy	50	Slovenia
11	China	31	Jordan	51	Spain
12	Costa Rica	32	Kazakhstan	52	Sweden
13	Croatia	33	Latvia	53	Switzerland
14	Czech Republic	34	Lithuania	54	Tanzania
15	Denmark	35	Macedonia	55	Thailand
16	Ecuador	36	Malawi	56	Tunisia
17	Egypt	37	Malaysia	57	Turkey
18	Estonia	38	Mexico	58	Ukraine
19	Finland	39	Moldova	59	United Kingdom
20	France	40	Morocco	60	United States

4. Methodology

This study utilize the panel linear regression with exogenous covariates to examine the relationship between the economic growth and the determinants such as road development, export level, education level, physical capital stock and urbanization level. In the panel linear regression, either a fixed-effects (FE) or random-effects (RE) model is employed to control for heterogeneity, as well as offered consistent and efficient estimates of model parameters in the existence of heterogeneity [41]. The FE model supposes that the country-specific intercept is correlated with the independent variables, on the other hand the RE model supposes that the country-specific intercept is a component of error term and not correlated with the independent variables [42]. The Hausman test was used to examine whether the FE model or RE model is more suitable. The null hypothesis is the country-specific intercept is not correlated with the independent variables and, therefore, rejection of null hypothesis indicates FE model is more suitable than RE model [41, 43-44].

As discussed earlier, road infrastructure development and other socioeconomic factors (export, education, physical capital stock and urbanization) facilitates economic growth. To examine these effects, a modified version of the framework developed by Fan and Chan-Kang [3] based on the Cobb-Douglas production function was adopted and the FE models were found to be more appropriate to

describe the relationship between various factors and economic growth. The FE model for the panel linear regression can be written as follows.

$$rgdpch_{it} = \alpha_i + \mu_1 roadpp_{it} + \mu_2 roadpp_{it} \cdot exp_{it} + \lambda_1 urb_{it}^2 + \lambda_2 urb_{it} + \beta_i X_{it} + \varepsilon_{it} \quad (1)$$

where the dependent variable 'rgdpch' is the proxy for economic growth, sub-index *i* denotes country, *t* denotes period of time; α_i is the country-specific intercept (FE); μ , λ and β are the model parameters; ε is the error term; 'roadpp' is the proxy to measure the road infrastructure development, roadpp-exp is the interaction variable between the 'roadpp' and 'exp'; 'urb' is the proxy to measure the urbanization level, X are other independent variables which includes, 'exp', 'edu' and 'kpw' that act as proxies for measuring country's export level, education level and physical capital stock per worker, respectively.

5. Results and Discussions

Table 3 shows the descriptive statistics for the dependent and all the independent variables used in the analysis.

Table 3. Descriptive statistics.

Variable	Obs	Mean	Std. Dev	Min	Max
rgdpch	1174	15316.73	12187.87	431.42	51798.08
roadpp	1174	9.78	9.38	0.58	62.02
exp	1174	6128.50	6361.51	44.86	36060.10
edu	1174	791.30	743.34	11.05	3575.11
kpw	1174	1.46e+14	3.55e+14	2.14e+11	3.32e+15
urb	1174	3.18	4.87	0.16	41.39

Table 4 reports correlation matrix between all independent variables used in the panel linear regression analysis. The highest correlation observed was 0.7802 between 'edu' and 'exp'. Multicollinearity did not appear to be a major issue because the correlation coefficient is not greater than 0.8 [42]. Overall, the Hausman test results show that the FE models are more suitable than RE model for the panel data set.

Table 4. Correlation matrix.

	roadpp	exp	edu	ln(kpw)	urb
roadpp	1.0000				
exp	0.5011	1.0000			
edu	0.5958	0.7802	1.0000		
ln(kpw)	0.1031	0.1441	0.3185	1.0000	
urb	0.1402	0.4080	0.3411	0.0903	1.0000

In Table 5, five models were used to describe the individual relationship between each independent variable and economic growth for all countries. Model A, B, C, D, and E investigated the relationship between economic growth with road length per population, export level, education level, physical capital stock per worker and urbanization level, respectively.

Table 5. Estimates of economic growth.

DV = rgdpch	Model				
IV	A	B	C	D	E
roadpp	293.35**				
exp		1.06**			
edu			12.63**		
ln(kpw)				4491.90**	
urb ²					-62.80**
urb					4844.45**
constant	12449.15**	8835.70**	5323.30**	-125581.9**	2051.55**
no. of observations	1174	1174	1174	1174	1174
no. of groups	60	60	60	60	60
R ² (within) sample	0.10	0.78	0.72	0.49	0.34
Overall model significance	177.61	417.57	66.09	435.3	302.38
Hausman test (chi-square)	13.44**	17.59**	42.76**	9.25*	24.50**
Turning point					38.57

Remarks: ** significant at 1%, * significant at 5%

In Table 6, Model F was used to investigate the relationship between economic growth and all the independent variables. The road length per population was interacted with export level to measure the interaction effect of these variables on economic growth as shown in Models G, H and I. As the interaction variable was the combination of the independent variables, the presence of it together with the independent variables in the regression can lead to multicollinearity. To address this issue, the independent variables ‘roadpp’ and ‘exp’ were removed from the model when the effects of the interaction variable was tested in Model G. In models H and I, the independent variable ‘roadpp’ and ‘exp’ was added one-by-one to check the multicollinearity between the interaction variable with the independent variable. Model J is the full model consisted all the independent variables, including the interaction variables. The presence of the interaction variable ‘roadpp*exp’ and ‘roadpp’ has a high correlation of 0.8151 that caused multicollinearity in models H and J.

Table 6. Estimates of economic growth.

DV = rgdpch	Model				
IV	F	G	H	I	J
roadpp	35.36**		-269.40**		-44.49*
roadpp*exp		0.012**	0.023**	0.0033**	0.0059**
exp	0.60**			0.54**	0.49**
edu	5.39**	7.58**	6.40**	5.34**	5.33**
ln(kpw)	991.67**	1449.29**	1563.50**	1035.70**	1088.54**
urb ²	-13.33**	-15.48**	-15.58**	-13.76**	-13.91**
urb	634.32**	931.54	885.95**	674.57**	688.15**
constant	-25630.65**	-39675.47**	-40536.94**	-26656.26**	-27868.16**
no. of obs.	1174	1174	1174	1174	1174
no. of groups	60	60	60	60	60
R ²	0.89	0.84	0.8706	0.89	0.90
Overall model significance	264.79	105.05	132.93	139.19	122.16
Hausman test (chi-square)	754.86**	215.09**	511.94	93.29**	1811.89**
Turning point	23.80	30.09	28.44	24.52	24.73

Remarks: ** significant at 1% and * significant at 5%

Models A and F showed that road length per thousand population was positive and statistically significant to economic growth while Models H and J showed that the relationship is negative but still statistically significant. The negative and statistically significant relationship in Models H and J was attributed to multicollinearity. In general, the growth of road length per thousand population would increase the economic growth. This is in line with previous research [1-6] as development of road

infrastructure would contribute substantially to economic growth.

Models B, F, I and J showed that export was positive and statistically significant to economic growth. This result is consistent with the results implied by previous research in which export growth promotes economic growth and in turn, creating more opportunities in employment and improve productive capacity within a country [23-27].

In common with previous studies [17-18], education level was positively significant with economic growth as seen in Models C, F, G, H, I and J. Thus, these results imply that education is an important socioeconomic factor that contributed substantially to economic growth. The physical capital stock per worker was also positively related to economic growth, as shown in Models D, F, G, H, I and J which is in accordance with previous studies [14-16].

Consistent with the findings of previous studies [38-40], the results confirmed a statistically significant inverted U-shaped dependent relationship between urbanization and economic growth. The estimated turning point of 'urb' in Model I was 24.52, which was at about 97th percentile of the urbanization data.

The estimations in Table 6 also demonstrated that the coefficient for the interaction variable between the 'roadpp' and 'exp' in Models G, H, I and J was positively significant with economic growth. This shows that the road infrastructure development enhance the effect of export on economic growth. This is particularly true as the development in road infrastructure could improve the transport efficiency for delivering export goods.

6. Conclusion and Recommendations

This study discussed the effect of road infrastructure development (i.e. the growth of road length per thousand population) and other socioeconomic factors (i.e. exports, education, physical capital stock and urbanization) on economic growth. The results indicated that road infrastructure development, export, education and physical capital stock per worker contributed substantially to economic growth. This implies that policies to improve road infrastructure development, export, education and physical capital stock should be carried out hand-in-hand in order to sustain higher economic growth. Nevertheless, the inverted U-shape dependency relationship between urbanization and economic growth suggested that over urbanization (when $urb > 24.52$) would lead to a decrease in economic growth. As such, special attention should be paid when implementing the urban growth policy together with other socioeconomic development policies. Another key finding of this study was that the development in road infrastructure would lead to an increase in export growth that would also contribute to economic growth.

Several limitations of this study should be noted. First, the road length per thousand population was used in this study to describe the road infrastructure development without considering the road network capacity and connectivity. It is no doubt that countries with greater road network capacity and connectivity would certainly have greater impact on economic growth. Second, besides socioeconomic factors describe in this study, empirical research also shows that improvements in other transport facilities such as railways [45-46] and infrastructures such as telecommunications [47-48] contributed substantially to economic growth. Thus, including these factors in further study could definitely provide a more comprehensive overview on the factors affecting a country's economic growth.

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