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Modeling the Transport Infrastructure-Growth Nexus in the United States

by Junwook Chi and Jungho Baek

The rising government funding in transport infrastructure has sparked political and academic debates on the economic impacts of transport infrastructure investment in the United States. Although numerous empirical studies have examined the transport infrastructure-growth nexus, existing literature has mixed conclusions of the economic effects of expanding transport infrastructure. The main objective of this paper is to assess the short- and long-run impacts of transport and non-transport public infrastructure on economic growth to provide an implication of the effectiveness of these fiscal policy tools in the short- and long-term. For this purpose, we employ a modern autoregressive distributed lag (ARDL) approach to explore the dynamic relationships among transport infrastructure, non-transport public infrastructure, private capital, labor hours, GDP, and exports. In the long run, we find that a bidirectional relationship exists between transport infrastructure and GDP, suggesting that expanding transport infrastructure improves aggregated economic output, and enhanced economic output increases public investment in transport infrastructure. However, the magnitude of the impact of transport infrastructure on GDP is smaller than that of non-transport public infrastructure, implying that non-transport infrastructure investment is a more effective long-term fiscal stimulus than expanding transport infrastructure.

INTRODUCTION

Public investment in transport infrastructure is often used as a form of fiscal stimulus in the United States. On February 26, 2014, President Obama announced $600 million of transportation funding and outlined his vision of a $302 billion, four-year surface transportation reauthorization proposal. Approximately $63 billion will be used to fill the funding gap in the Highway Trust Fund. His vision includes creating jobs and improving the U.S. economy and private investment, while also increasing access to jobs and U.S. exports (White House 2014). According to the Federal Highway Administration (2014), public investment in highway and street infrastructure has grown to $78.42 billion in 2012, more than a 103% increase over 1960 ($38.49 billion). The rising government spending on transport infrastructure has raised political and academic debates on the economic impacts of expanding transport infrastructure investment in the U.S.

Several empirical studies have examined the effectiveness of transport infrastructure investment as a fiscal stimulus on economic growth, referred to as the *transport infrastructure-growth nexus*. A group of studies support the traditional notion that an increase in transport infrastructure investment improves economic growth through an increase in aggregate productivity (e.g., Munnell 1992; Garcia-Mila and McGuire 1992; Bajo-Rubio and Sosvilla-Rivero 1993; Fernald 1999; Ozbay et al. 2003 and 2007; Jiwattanakulpaisarn et al. 2010; Pereira and Andraz 2012; Pradhan and Bagchi 2013; Agbelie 2014; Blonigen and Cristea 2015). Pradhan and Bagchi (2013), for example, provide empirical evidence of bidirectional causal relationship between road transportation and economic growth. Jiwattanakulpaisarn et al. (2010) use panel data from 48 U.S. states and find that highway infrastructure investment can have a positive effect on state employment growth. Pereira and Andraz (2012) use output, employment, and highway investment data and find a positive impact of highway investment on regional economy at both aggregate and state levels.

Another group of studies, on the other hand, provide evidence that government spending on transportation infrastructure has an insignificant or little impact on growth (e.g., Garcia-Mila et al.

1996; Evans and Karras 1994; Holtz-Eakin 1994; Chandra and Thompson 2000; Berechman et al. 2006; Padeiro 2013) Chandra and Thompson (2000), for example, find that the effect of expanding public infrastructure (i.e., interstate highways) on economic activity remains unclear due mainly to the so-called "leakages" effect of investment across regions and industries. Berechman et al. (2006) also show that a public investment in highway infrastructure indeed produces strong spillover effects relative to space and time, thereby raising questions about the validity of the results obtained by previous studies.

Although the literature on the transport infrastructure-growth nexus is fairly large, several questions still remain unsolved. First, due to mixed conclusions on the transport infrastructure impacts, there is a lack of information on evaluating the effectiveness of government spending on *transport* and *non-transport infrastructure* (e.g., schools, hospital, and other public buildings) as an economic stimulus; hence, it is difficult for policymakers to determine which fiscal policy tool is more effective to boost the economy. Second, given that the economic impacts of infrastructure investment may become substantially weaker over time (Berechman et al. 2006), little attention has been paid to examination of both the short- and long-run effects together. Third, the direction of the causal relationship has not been well documented in existing literature (Jiwattanakulpaisarn et al. 2010). If transport infrastructure and economic growth are cointegrated, there must be Granger causality in at least one direction. The Granger causality test can be used to investigate whether one variable causes the other variable, which will improve understanding of the directional effects (e.g., unidirectional or bidirectional causality). Yet, only a few studies have attempted to examine the causal effect of transport investment on economic growth and the possible reverse impact of economic growth on public capital development. Tong et al. (2014), for example, show that the reverse causality from GDP to transport infrastructure is present, and transport infrastructure Granger causes exports in the U.S. However, their study only focused on the short-run dynamics based on the concept of Granger causality.

The main objective of this paper is to expand the scope of the previous work by re-examining the effects of various macroeconomic aggregates and transport infrastructure variables on economic growth with an enhanced time series econometrics – an autoregressive distributed lag approach to cointegration (referred to as the ARDL model). Empirical focus is on examining the short- and long-run relationships among *transport infrastructure*, *non-transport public infrastructure*, private capital, labor, economic output (GDP), and exports in the U.S. The ARDL model has several advantages in contrast to other conventional cointegration methods. It is efficient to determine cointegration relationship even if the sample size is small and finite. In addition, it can be applicable irrespective of whether the underlying regressors are *I(0)*, *I(1)*, or mutually cointegrated as opposed to other cointegration techniques such as the Johansen and Juselius approach (Johansen and Juselius 1992) assuming that all variables must be integrated at the same order. More importantly, there is no study that simultaneously analyzed the short- and long-run relationships among the selected variables in the existing literature. Through a simple linear transformation, the error-correction model (ECM), which is derived from the ARDL model, simultaneously estimates short- and long-run coefficients. In this paper, the ARDL is the cointegrating (long-run) relationship to determine directional relationships among the selected variables.[1] This dynamic approach will shed new light on dynamic interrelationships among transport and non-transport infrastructure investment and economic growth, and will contribute to the literature of transportation economics. The remaining sections present the model, ARDL modelling, data, empirical findings, and concluding remarks.

THE MODEL

It should be emphasized at the onset that, because the transport infrastructure and economic growth relationships typically estimated in the existing literature are not driven by any particular economic model, little theoretical guidance is available for the correct specification. In tackling this issue, therefore, we rely on an analytical framework addressed by Gillen (1996). This formulates the aggregate production model in which economic output (GDP) in a country typically responds to changes in capital stock of transport (T) and non-transport (G) infrastructure, private capital (K), and labor (L). Since exports increase economic growth, in the empirical model used here we extend the standard model to include exports as is done in Tong, Yu, and Roberts (2014).

In examining the transport infrastructure-growth nexus empirically, we use the ARDL approach developed by Pesaran et al. (2001). To explain the ARDL procedure, we start with a vector of two variables z_t, where $z_t = (y_t, x_t')'$, y_t is the dependent variable and x_t is a vector of regressors. Following Pesaran et al. (2001), we then formulate the conditional error correction model (ECM) of interest as follows:

$$(1) \quad \Delta y_t = \alpha_0 + \pi_y \, y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta x_{t-j} + \theta w_t + u_t$$

where α_0 is the constant; π_{yy} and π_{yx} are the long-run parameters; δ_i and γ_i are the short-run parameters; and w_t is a vector of exogenous variables (i.e., dummy variables). The ARDL procedure for identifying for the existence of a long-run relationship between y_t and x_t is through the testing of the joint significance of the lagged levels of variables (y_{t-1} and x_{t-1}) in Equation (1). This is equivalent to testing the null hypothesis of $H_0 : \pi_{yy} = 0, \pi_{yx.x} = 0'$ (no cointegration) against the alternative hypothesis of $H_0 : \pi_{yy} \neq 0, \pi_{yx.x} \neq 0'$, using the standard F-test. Narayan (2005)[2] provides two sets of critical values covering all possible classification of the variables into $I(0)$ or $I(1)$ processes; for example, the upper bound values assume that all the variables are $I(1)$, and the lower bound values assume that they are $I(0)$. If the computed F-statistic falls outside the critical value bounds, a conclusive decision can be made; for example, if the computed F-statistic is higher (lower) than the upper (lower) bound of critical values, then the null of no cointegration can (cannot) be rejected. If the F-statistic falls inside these bounds, inference is inconclusive.

DATA AND EMPIRICAL PROCEDURE

Data

Annual data between 1960 and 2012 are collected to estimate Equation (1). The time span is dictated by availability of the data for every series. Following Tong et al. (2014), highway and street infrastructure (T_t) is used as a proxy for transport infrastructure investment. In 2012, for example, the highway and street infrastructure was \$3.26 trillion, accounting for approximately 26% of total government fixed assets (\$12.52 trillion) (BEA). The value of the net stock of government fixed assets (excluding national defense and highways and streets) (G_t) is used as proxy for non-transport capital of the U.S. government. The value of private nonresidential-fixed assets (including equipment, software, and structures) (K_t) is used as proxy for private capital in the U.S. The gross domestic product (GDP_t) is used as a proxy for economic output. The value of exports (EX_t) is used to measure the impact of transport investment on trade. The labor (L_t) represents the combined hours of domestic full-time and part-time employees. All variables are collected from the Bureau of Economic Analysis, U.S. Department of Commerce (BEA 2014). The GDP deflator (2009=100) obtained from the BEA is used to derive real values. Table 1 summarizes our data. Natural logarithms of the variables are used in the analysis. Figure 1 shows logarithms and first differences of the variables. As seen in the figure, transport infrastructure investment has consistently increased since 1960. The recent increase in government funding in transport infrastructure has sparked debates on the economic impacts of transport infrastructure investment and it is the empirical focus of this study.

Table 1: Descriptive Statistics of Variables (1960-2012)

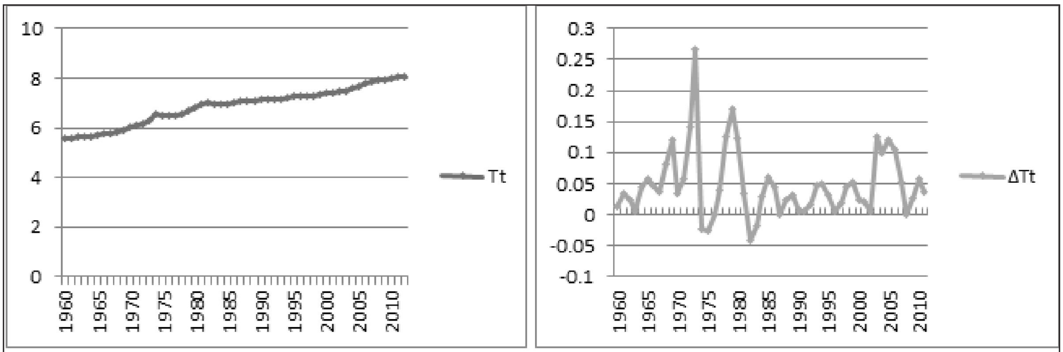
Variable	Description	Mean	Standard Deviation	Minimum	Maximum
T_t	Highway and street infrastructure (billions of 2009 dollars)	1,213	810	264	3,199
G_t	Non-transport public capital (billions of 2009 dollars)	2,978	2,045	508	7,406
K_t	Private capital (billions of 2009 dollars)	8,063	5,186	1,648	17,830
L_t	Labor hours (millions of hours)	180,790	38,927	114,607	237,050
GDP_t	Gross Domestic Product (billions of 2009 dollars)	8,563	3,882	3,109	15,369
EX_t	US exports (billions of 2009 dollars)	709	590	79	2,107

Empirical Procedure

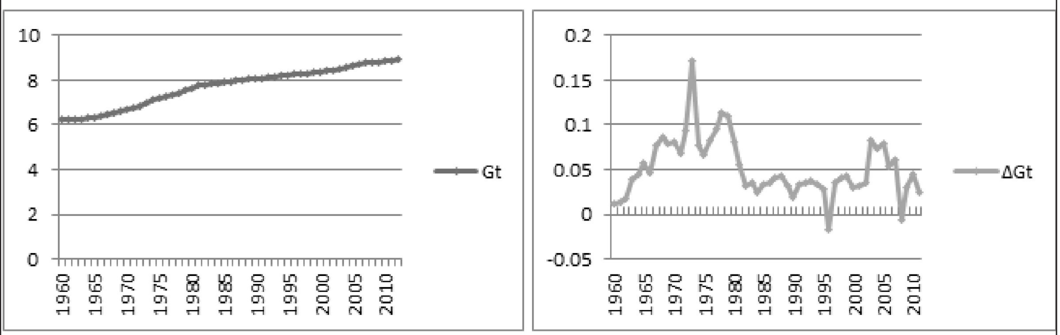
As mentioned earlier, unlike conventional applications of cointegration analysis (i.e., Johansen 1988), the ARDL can be applicable even when it is not known with certainty whether the underlying regressors are $I(1)$ or $I(0)$; hence, this method does not require a unit root test to determine the order of integration each variable exhibits. Ouattara (2004), however, proves that the bounds test cannot be applicable to $I(2)$ processes. Before implementing the ARDL modeling, therefore, it is necessary to conduct a unit root test to make sure that none of the variables are $I(2)$ variables.

To determine the order of integration in the selected variables, we employ the Dickey Fuller Generalized Least Squares (DF-GLS) and the Phillips-Perron (PP) unit root tests (Table 2). The results show that for T_t, G_t, L_t, GDP_t and EX_t, the null hypothesis of nonstationarity cannot be rejected for the level, while it can be rejected for the first difference of the variables at least at the 10% significance level, indicating they are $I(1)$ variables. We find the mixed findings between the two unit root tests for K_t, indicating that these variables can be $I(0)$ or $I(1)$ processes. From these findings, therefore, we conclude that all the variables must be either $I(0)$ or $I(1)$ processes and the ARDL can be pursued on them safely.

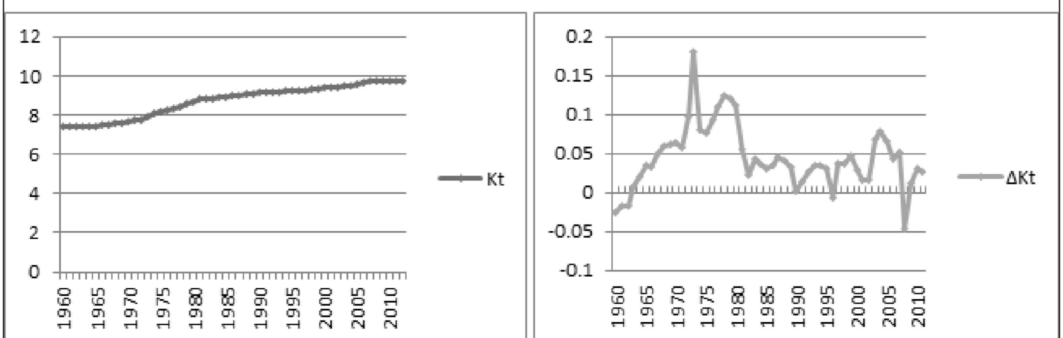
Figure 1: Logarithms and First Differences of the Variables from 1960 to 2012



Logarithms and first differences of T_t

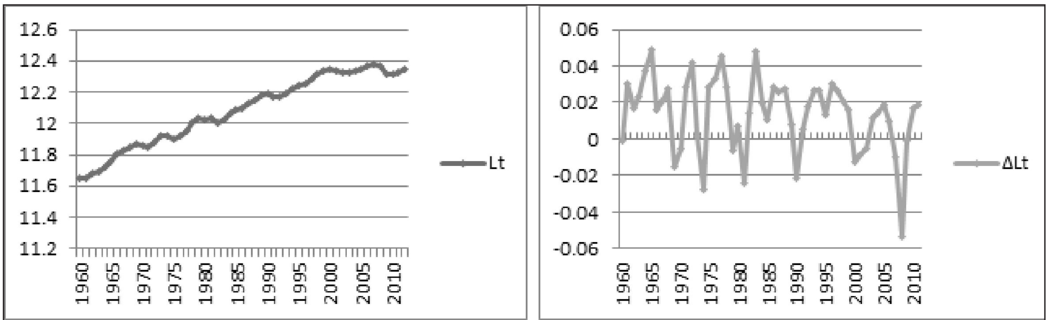


Logarithms and first differences of G_t

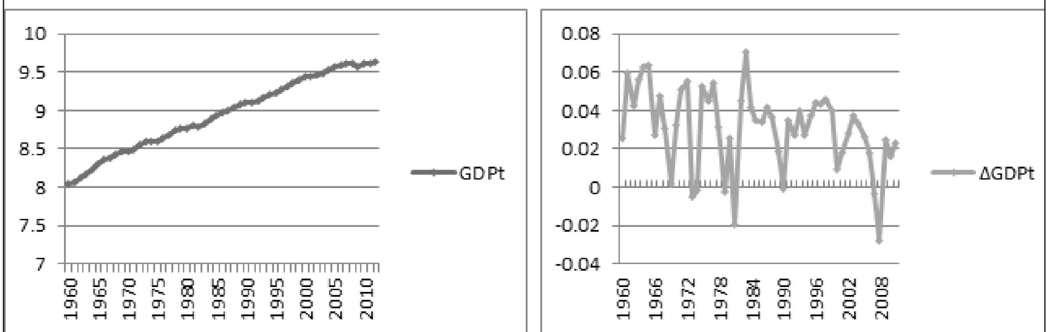


Logarithms and first differences of K_t

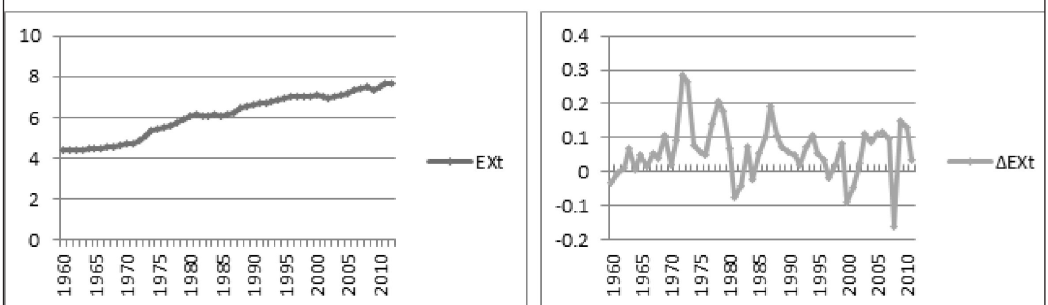
(Figure 1: continued)



Logarithms and first differences of L_t



Logarithms and first differences of GDP_t



Logarithms and first differences of EX_t

Table 2: Results of Unit Root Tests

Variables	Dickey Fuller GLS (DF-GLS) test		Phillips-Perron (PP) test		Decision
	Level	First difference	Level	First difference	
T_t	-2.077	-4.634**	-0.581	-4.443**	I(1)
G_t	-1.111	-3.005*	-1.419	-3.133**	I(1)
K_t	-1.578	-3.175*	-2.674*	-	I(1)/I(0)
L_t	-0.738	-5.411**	-2.165	-4.759**	I(1)
GDP_t	-1.267	-4.890**	-2.560	-4.924**	I(1)
EX_t	-2.164	-3.912**	-0.582	-4.846**	I(1)

Notes: ** and * denote rejection of the null hypothesis of a unit root at the 5% and 10% level, respectively; Schwert criterion is used to determine the lag length for DF-GLS tests; For PP test, the 5% and 10% critical values are -2.928 and -2.599, respectively; The PP test uses Newey-West standard error to account for serial correlation.

As discussed above, Pesaran et al. (2001) recommend implementing an *F*-test to determine the existence of a long-run (cointegration) relationship among the variables. If the lagged-level variables – that is, $H_0 : \pi_{yy} = 0, \pi_{yx.x} = 0'$ in Equation (1) - are jointly significant, the null hypothesis of non-existence of the long-run relationship can be rejected. For this, a maximum of six lags is imposed on each first differenced variable and the Schwarz Bayesian Criterion (SBC) is used to select the optimal lags.[3] The results show that the calculated *F*-statistics are statistically significant at the 5% level when using $T_{t,}$ G_t, and GDP_t as the dependent variables (Table 3). On the other hand, the calculated *F*-statistics using $K_{t,}$ $L_{t,}$ and EX_t as the dependent variables are not statistically significant at the 5% level.[4] This suggests there is a long-run relationship among the variables only when $T_{t,}$ G_t, and GDP_t are used as dependent variables; hence, these three equations are used to estimate the short- and long-run relationships among the variables.

Table 3: Results of Bounds Testing Procedure

Dependent variable	Cointegration hypothesis	F-statistic
T_t	$F(T_t \mid EX_t, GDP_t, G_t, K_t, L_t)$	4.855**
G_t	$F(G_t \mid T_t, GDP_t, EX_t, K_t, L_t)$	18.291**
K_t	$F(K_t \mid T_t, GDP_t, G_t, EX_t, L_t)$	1.919
L_t	$F(L_t \mid T_t, GDP_t, G_t, K_t, EX_t)$	2.558
GDP_t	$F(GDP_t \mid T_t, EX_t, G_t, K_t, L_t)$	5.928**
EX_t	$F(EX_t \mid T_t, GDP_t, G_t, K_t, L_t)$	1.653

Notes: ** and * denote rejection of the null hypothesis of a unit root at the 5% and 10% level, respectively; The order of lag is based on Schwarz Bayesian Criterion; The lower and upper critical values of Narayan (2005) at the 5% level (10% level) are 3.442 and 4.690 (2.927 and 4.068), respectively.

EMPIRICAL RESULTS

Results of the Long-run Analysis

Table 4 reports our key estimation results of the long-run analysis, where the dependent variables are represented in turn by GDP, transport infrastructure, and non-transport infrastructure as discussed earlier. For the GDP (GDP_t) equation, the estimated coefficient on the transport infrastructure is statistically significant at the 5% level and has a positive sign, indicating that expanding government investment on transport infrastructure indeed has a beneficial effect on economic growth in the long run. The coefficient of the non-transport capital has a significantly positive effect on GDP, suggesting that an increase in spending on non-transport infrastructure increases growth. The coefficients of the private capital and U.S. exports carry positive signs and are highly significant, implying that these factors are also important in affecting economic growth in the long run. The results reveal the importance of investment in the private sector as a key driving force of economic growth. However, the coefficient of labor is not statistically significant even at the 10% level, indicating that labor hours have little effect on economic growth in the U.S.

For the transport infrastructure (T_t) equation, the coefficient on the non-transport infrastructure is statistically significant at the 5% level and carries a positive sign, indicating that improved non-transport infrastructure, such as health care and education, tends to increase government spending on transport infrastructure in the long run. The estimated effect of the GDP is positive and highly significant, suggesting that economic growth improves public investment on transport infrastructure in the long run. Combined with the results from the GDP equation, this finding shows a significant two-way (bidirectional) relationship between transport infrastructure and economic growth in the U.S. In other words, U.S. economic growth is significantly affected by government investment on transport infrastructure, and transport infrastructure is also affected by U.S. economic growth. This finding contrasts with Tong et al. (2014) who find a unidirectional causation from economic growth to transport infrastructure.[5] The coefficient of labor carries a negative sign and is highly significant, implying that an increase in work hours by employees in domestic industries tends to reduce the need for government spending on transport infrastructure.

Finally, for the non-transport infrastructure (G_t) equation, the coefficient of the GDP is statistically significant at the 5% level and carries a positive sign, indicating that economic growth tends to improve government spending on non-transport infrastructure in the long run. In addition, the coefficient of the labor is highly significant and carries a negative sign, suggesting that an increase in work hours in domestic industries reduces government spending on non-transport infrastructure. Notice that labor is found to be highly significant in the transport and non-transport infrastructure equations, suggesting that labor conditions in the U.S. have a substantive effect on investment in public infrastructure. In other words, the U.S. government appears to increase an investment in both transport and non-transport infrastructures to stimulate economic growth during periods employment rates and works hours. However, the coefficients of the transport infrastructure and exports are statistically insignificant at the 10% level, indicating that they have little effect on U.S. non-transport infrastructure in the long run. Consistent with the findings of Voss (2002) and Narayan (2004), this study finds a lack of evidence of significant crowding in between private and public investment. Private capital has a significant positive effect on non-transport infrastructure, but it has an insignificant impact on transport infrastructure. A possible explanation for the insignificant relationship between private and public capital is that an increase in private capital investment can have both positive and negative effects on public capital investment, which may lead to the insignificant impact (i.e., zero net effect). A rise in private investment can encourage an increased allocation of resources toward public capital formation to stimulate the economy. However, it also can make a public infrastructure investment less attractive if expanding private capital reduces the need for government spending on infrastructure (substitutability between private and public stock).

Table 4: Results of Estimated Long-run Coefficients

Variables	GDP_t Equation	T_t Equation	G_t Equation
T_t	0.551** (0.195)	-	-0.188 (0.240)
G_t	1.023** (0.346)	1.958** (0.384)	-
K_t	0.978** (0.320)	0.368 (0.287)	0.903** (0.161)
L_t	0.578 (0.417)	-1.294** (0.501)	-1.835** (0.824)
GDP_t	-	0.929** (0.319)	1.464** (0.541)
EX_t	0.187* (0.112)	-0.016 (0.076)	-0.098 (0.080)

Notes: ** and * denote rejection of the null hypothesis at the 5% and 10% level, respectively; Parentheses are standard errors.

Results of the Short-run Analysis

We now turn our attention to the short-run dynamics, which are estimated by coefficient estimates of first-differenced variables in Equation (1) (Table 5). The results of the GDP equation show that the (lagged) coefficients of transport capital, private capital, labor, and exports are statistically significant at least at the 10% level, indicating that these variables are important determinants of U.S. growth in the short run. However, the coefficient of the non-transport infrastructure is not statistically significant even at the 10% level, showing a lack of significant relation between non-transport infrastructure and growth. This further suggests that government spending on non-transport infrastructure may not be an effective fiscal tool to deal with economic downturns in the short run.

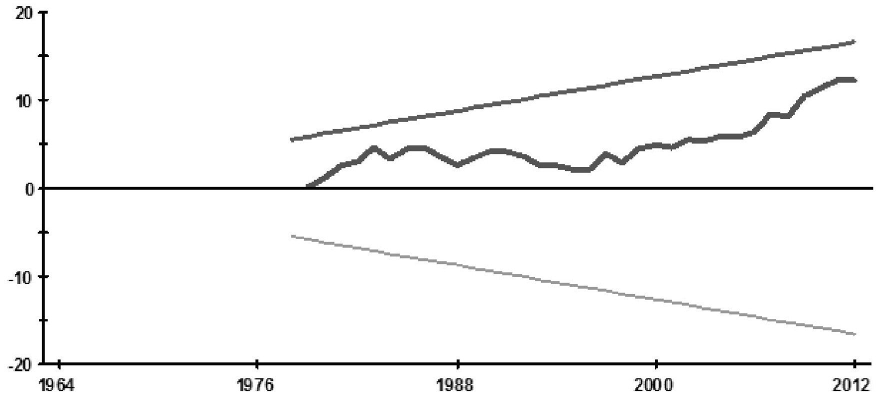
The results of the transport infrastructure equation show that the non-transport infrastructure, labor, and GDP have significant effects on transport infrastructure in the short run. These findings are consistent with those of long-run analyses. Finally, the results of the non-transport infrastructure equation show that the private capital and GDP have a significant short-run effect on non-transport capital. Unlike the long-run results, the transport infrastructure is found to have a significant effect on the non-transport infrastructure in the short run.

It is important to note that the coefficients of the error-correction terms (EC_{t-1}) carry negative signs and are highly significant for all three equations. This further provides evidence of a stable long-run relationship among the selected variables, thereby justifying our ARDL modeling. We employ CUSUM and CUSUMSQ tests to the residuals to check the stability and robustness of the estimated relationship. These tests show a plot of the recursive residuals and the pair of critical lines at the 5% significance level. Figure 2 illustrates that the CUSUM and CUSUMSQ statistics fall within the two critical lines, suggesting that the parameter estimates are stable. Finally, the estimated ARDL model passes all the diagnostic tests (Table 5).

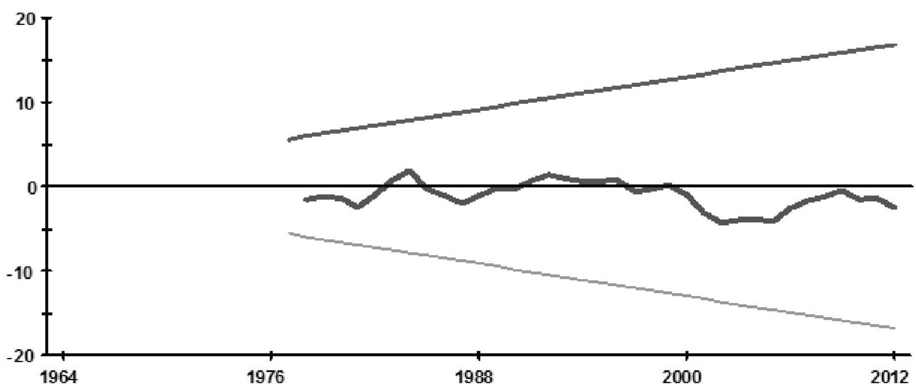
Figure 2: Test Results of Stability and Robustness of the Estimated Relationship (CUSUM and CUSUMSQ Tests)

I. Plot of cumulative sum of recursive residuals (CUSUM)

(a) GDP_t Equation



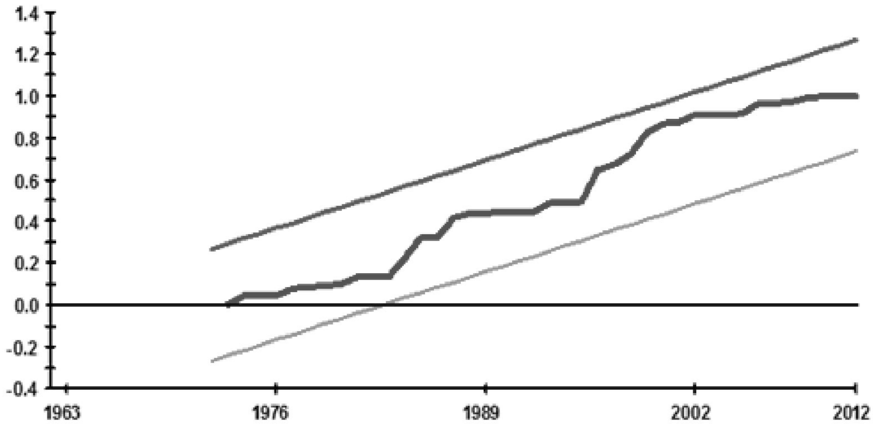
(b) T_t Equation



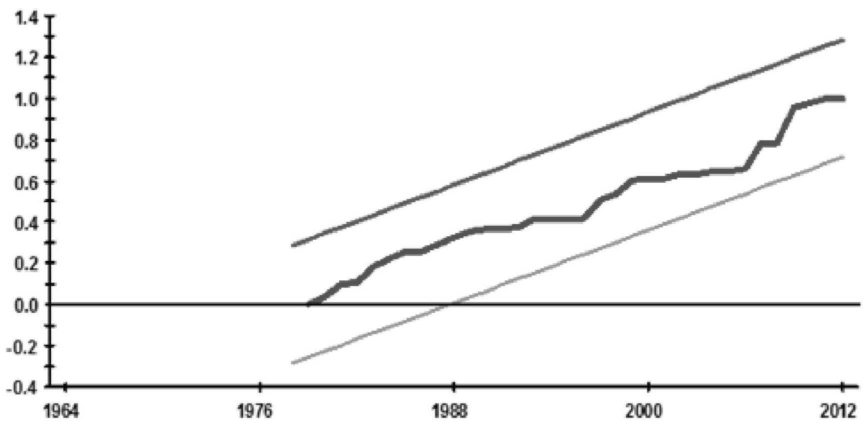
(c) G_t Equation

(Figure 2: continued)

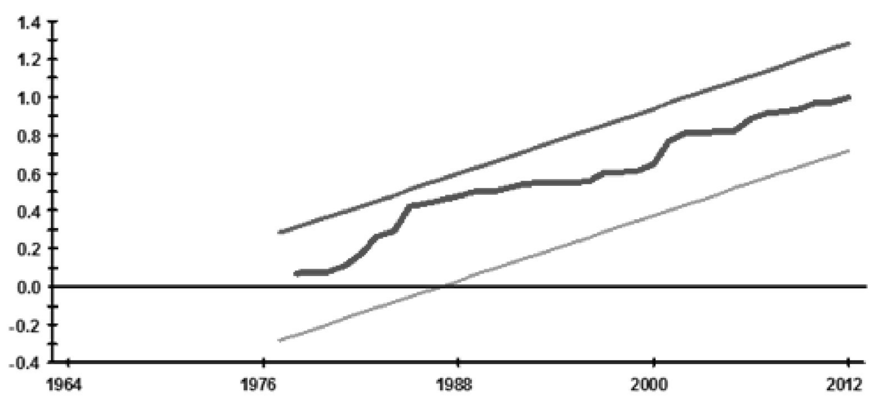
II. Plot of cumulative sum of squares of recursive residuals (CUSUMSQ)



(a) GDP_t Equation



(b) T_t Equation



(c) G_t Equation

Table 5: Results of Estimated Short-run Coefficients

Variables	Equation	Equation	Equation
ΔT_t	0.058* (0.021)	-	0.026 (0.032)
ΔT_{t-1}		0.462** (0.131)	-0.058** (0.025)
ΔT_{t-2}		0.361** (0.119)	
ΔG_t	-0.060 (0.043)	0.988* (0.255)	-
ΔK_t	0.103** (0.031)	0.341 (0.325)	0.843** (0.048)
ΔL_t	0.950** (0.076)	-0.653** (0.294)	0.050 (0.152)
ΔGDP_t	-	-0.369 (0.285)	-0.302** (0.137)
ΔGDP_{t-1}	-0.348** (0.066)	1.299** (0.309)	0.256** (0.074)
ΔGDP_{t-2}		0.666** (0.264)	
ΔEX_t	-0.019* (0.010)	-0.008 (0.038)	-0.013 (0.009)
EC_{t-1}	-0.105** (0.030)	-0.504** (0.109)	-0.136** (0.046)
$F(4)$ for serial correlation	1.667 [0.178]	0.410 [0.609]	1.776 [0.158]
$\chi^2(1)$ for heteroscedasticity	0.168 [0.682]	0.083 [0.772]	0.032 [0.857]
$\chi^2(2)$ for normality	0.056 [0.972]	0.411 [0.814]	3.017 [0.221]

Notes: ** and * denote rejection of the null hypothesis at the 5% and 10% level, respectively; The Lagrange multiplier (LM) test statistic of residual serial correlation is used (the null of no autocorrelation against lag length 4); Heteroskedasticity test is based on the regression of squared residuals on squared fitted values (the null is homoskedasticity); Normality test is based on a test of skewness and kurtosis of residuals (the null is a normal distribution); *P*-values for serial correlation, heteroscedasticity, and normality tests are in brackets.

CONCLUSIONS

This paper examines the short- and long-run relationships among transport infrastructure, non-transport public infrastructure, private capital, labor, economic output (GDP), and exports in the U.S. For this, an ARDL approach is applied to annual data over 1960 to 2012. Our key findings are summarized as follows: 1) a stable long-run cointegration relationship exists when using transport infrastructure, non-transport public infrastructure, and GDP as the dependent variables; 2) both transport and non-transport infrastructure investments have a positive long-run impact on economic growth; 3) economic growth, non-transport public infrastructure, labor are key determinants of transport infrastructure investment in the long run; and 4) economic growth, private capital, and labor are the long-run determinants of non-transport infrastructure.

Several policy implications can be derived from our empirical findings. First, we provide empirical evidence that there is a bidirectional relationship between transport infrastructure and growth in the long run, indicating that expanding transport infrastructure increases aggregated economic output, and enhanced economic output increases public investment in transport infrastructure. This implies that improving transport systems can be a stimulant to achieve economic growth in the U.S. Furthermore, as the U.S. economy grows, there will be a growing need for better transport infrastructure. According to the U.S. Congressional Budget Office (2014), real GDP is forecasted to grow by 3.4% in 2015 and by 2.7% in 2017, which would require a more efficient national transportation network and better accessibility.

Second, our findings show that the magnitude of the impact of non-transport public infrastructure (+1.023) is greater than that of transport infrastructure (+0.551) on economic output in the long run. Consistent with Cullison (1993), we find evidence that expanding non-transport public infrastructure has a relatively large economic impact compared with expanding transport infrastructure capital. Thus, expanding non-transport infrastructure can be a more effective long-term fiscal stimulus, compared with expanding transport infrastructure. As noted by Talley (1996) and Tong et al. (2014), substantial transport infrastructure already exists in the U.S., implying that further investment in transport infrastructure can have little impact on economic growth and development. The U.S. economy has recovered from the economic recession of the 2008 financial crisis, but annual economic growth has been only about 2% on average, which is still well below its historical average (Appelbaum 2014). Based on the findings of this paper, more resources should be allocated to non-transport public capital than transport infrastructure to enhance the effectiveness of fiscal policy and stimulate the stagnant economy.

Finally, the impacts of public infrastructure investment on the GDP are found to vary between long and short run. For non-transport public infrastructure, the results reveal that its long-run impact is positive and significant, while its short-run effect is found to be insignificant. These findings suggest that government spending on public infrastructure could be a more valuable fiscal policy tool to achieve long-term economic growth, rather than a short-term economic stimulant.

This study could be extended in several directions. Future research could investigate the transport infrastructure-growth nexus by taking into account stock and flow approaches. For example, the economic effects of transport infrastructure between the two approaches could be analyzed and compared to provide various implications. Although the scope of this study is limited to transport and non-transport infrastructure, the short- and long-run relationships among public infrastructure, non-infrastructure, and macroeconomic variables could be further investigated. By using this approach, the effectiveness of infrastructure investment at a country level can be evaluated.

Endnotes

1. Although the issue of stock or flow approach is well known in the analysis of the infrastructure-growth nexus, following the relevant studies on the issue, we employ the stock approach in our empirical modeling.

2. Note that the method using the two sets of critical values is first proposed by Pesaran et al. (2001) and they are widely used in literature. However, Pesaran's critical values are based on large sample sizes (e.g., 500-1,000 observations) and cannot be applied for the small sample size. Due to the fairly small samples (53 observations), Narayan's critical values for small sample size are employed in this study.

3. The optimal lags for the equation are $ARDL_{(2,0,0,0,1,0)}$. For and equations, this study uses the optimal lags of $ARDL_{(3,0,3,0,0,2)}$ and $ARDL_{(1,2,0,2,1,1)}$, respectively.

4. The upper critical value at the 5% level is 4.690. If the computed *F*-statistic lies above (below) the upper (lower) critical value, the selected variables are (not) said to be cointegrated.

5. The mixed results on the direction of causation may be derived from the methods. Tong et al. (2014) draw their conclusion based on Granger causality test using VAR models, which mainly focus on the short-run dynamics. In contrast, we use a modern ARDL approach which allows for a simultaneous analysis of the short- and long-run dynamics. Using ARDL approach, we identify cointergration vectors and determine the direction of causation among the variables.

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