Dynamics of Transport Infrastructure, Exports and Economic Growth in the United States

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This paper focuses on the dynamic relationships among transport infrastructure, exports and economic growth in the United States using a multivariate time-series analysis. Results suggest that the formation of highways and streets affects economic growth indirectly through enhancing the capital stock of non-transport infrastructure and crowding in private capital. The reverse causality from economic output to highway and street infrastructure is observed. Aggregate capital stock of non-transport infrastructure, excluding national defense, has sustainable positive effects on economic output and exports over a number of years. Empirical evidence also shows that highway and street infrastructure and non-transport infrastructure Granger cause exports.

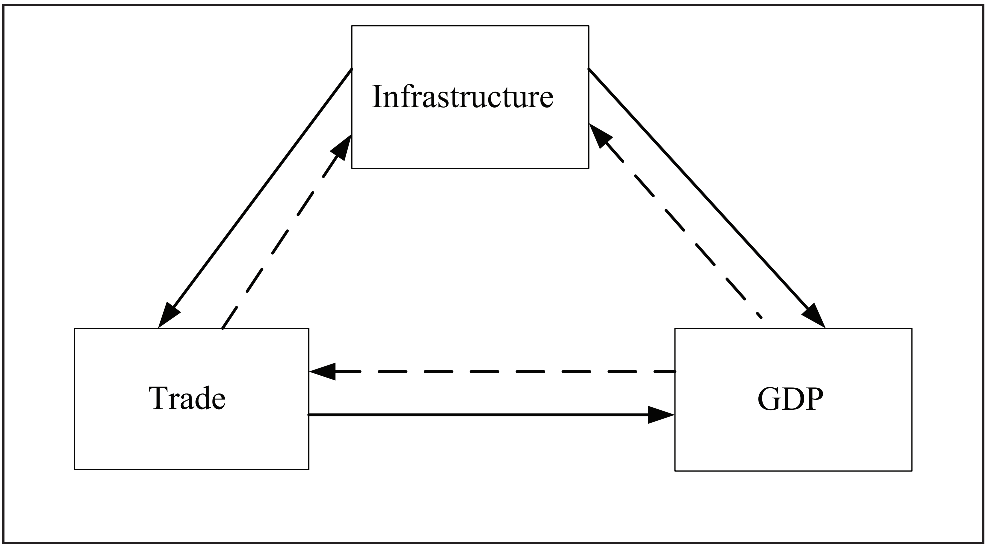
INTRODUCTION

Government spending on transport infrastructure has long been considered a means to enhance economic development in both developed and developing countries. The significance of transport infrastructure investment has been clearly revealed in the U.S. government's proposals and policies over decades. For example, in President Clinton's 1992 presidential campaign document, he proposed a "Rebuild America Fund" to allocate $20 billion annually for four years in four critical areas, including transportation, information network, environmental technology, and defense conversion (Clinton 1992). President G. W. Bush signed the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) in 2005, allocating more than $286 billion over five years to maintain and improve the surface transport infrastructure of the nation. To address the economic recession in the late 2000s, President Obama signed the American Recovery and Reinvestment Act (ARRA) in 2009 that included $48 billion for transport infrastructure. In 2011, Mr. Obama proposed investing an additional $50 billion to modernize national highways, transit, rail, and aviation infrastructure systems in the American Jobs Act. In June 2012, a new surface transportation bill of $105 billion over two years, Moving Ahead for Progress in the 21st Century (MAP-21), was signed into law to reauthorize the federal-aid highway program.

Interestingly, regardless of the aforementioned policy focus, a consensus remains elusive about the effects of transport infrastructure on economic growth at the aggregate level (Pereira and Andraz 2012). The potential connection between economic development and transport infrastructure investment in the United States has been at the forefront of academic debates over decades. A number of empirical studies suggest that government expenditures on public infrastructure, including transportation, can potentially increase productivity or reduce cost of production and, hence, increase economic growth (e.g., Aschauer 1989, Munnell 1990, Fernald 1999, Glass 2008, Pereira and Andraz 2012). Alternatively, others find no significant effect or even a negative impact on national productivity (e.g., Holtz-Eakin 1994, Garcia-Mila et al. 1996, Ewing 2008). Notwithstanding the diverse perspectives regarding transport infrastructure investment, the recent global economic recession has encouraged some policy makers to utilize this fiscal policy tool to promote economic recovery, reinforcing the debate about the economic impact of infrastructure investment.

The role of trade in the relationship between transport infrastructure and economic growth typically has been ignored in previous literature. Trade could contribute to both economic growth

Figure 1: Dynamic Relationships Among Transport Infrastructure, Trade and Economic Output



and transport infrastructure (see Figure 1). The export-led growth hypothesis suggests that exports can be an engine for economic growth to increase employment and income in the exporting country, increase the efficiency of resource allocation, and achieve economies of scale (Marin 1992, Giles and Williams 2000). Similarly, trade expansion potentially stimulates the need for and development of transport infrastructure (Borrone 2005, Lee and Rodrigue 2006, Beningo 2008). Conversely, economic growth and infrastructure development in a country can affect trade. Domestic economic conditions, including strong product demand and/or agglomeration economies, can promote the growth of exports (e.g., Leichenko 2000, Zestos and Tao 2002). In addition, researchers have confirmed a positive relationship between transport infrastructure and trade through lower transportation cost or better infrastructure quality (Limao and Venables 2001, Nordas and Piermartini 2004).

The aim of this research is to revisit the long-term impact of transport infrastructure on U.S. economic growth by incorporating trade as an element of the analysis. Including trade in the model can mitigate the omitted-variable problem, thus improving the three-way impact estimates. Our hypothesis is that enhancing transport infrastructure can increase economic output in the United States. The hypothesis is empirically tested using a multivariate time-series framework, which can address the issue of nonstationary data and provide a clearer understanding of the long-run relationships among these variables. Most importantly, the analysis provides policy makers updated and more accurate information for more efficient allocation of scarce budget resources to infrastructure investments.

The remainder of this article is organized as follows: a brief literature review about the relationships among economic growth, trade and infrastructure is provided in the next session, followed by an explanation of the analytical methods. A description of the data and empirical analysis are then presented. Policy implications and conclusions are offered in the final section.

LITERATURE REVIEW

The economic impact of transport infrastructure investment (either in terms of government spending on transport infrastructure per year or the accumulated stock of transport infrastructure capital) has been scrutinized since the work of Aschauer (1989). Thorough and updated surveys of the relevant literature are available in Baird (2005) and Goetz (2011). Goetz included the summary of the literature prior to 2000 by Bhatta and Dremman (2003) and analyzed 55 additional papers published on ISI Web of Science from 1999 to 2009. Among more than 100 reviewed studies, most find that investment in transport infrastructure supports one or more indicators of economic growth. Specifically, 43 of the 55 more recent studies confirm the positive role of transport infrastructure investment. A brief summary of various perspectives on the role of transport infrastructure is presented below.

Aschauer (1989) estimated the impact of "core" infrastructure (streets, highways, airports, and water systems) on economic growth and productivity in the United States during 1949−1985, and reported elasticities of government capital ranging from 0.38 to 0.56, and Munnell (1990) estimated an elasticity of output with respect to infrastructure near 0.34 in a national study. However, these estimates have been criticized because of the issues of spurious relationships, simplified structural form and the aggregated data used for analysis (Gramlich 1994). Using the data from 48 contiguous states, Munnell and Cook (1990) reported a lower output elasticity of public capital of 0.15. The use of less aggregated state or county data by others also yielded smaller positive effects of transport infrastructure on economic growth (e.g., Berechman et al. 2006, Pereira and Andraz 2012). In addition, a number of case studies for particular states or counties suggested positive impacts of highway and street infrastructure development on local or regional economic activity (e.g., Babcock and Leatherman 2011, Wang et al. 2013). Other researchers measured the "broader" economic effects of transport infrastructure by considering the spillover (indirect) effects on neighboring geographic areas, attempting to enhance the precision of the effects of infrastructure (Cohen 2010, Tong et al. 2013). Besides, others confirmed the positive effects of transport infrastructure on activities in the private sector (e.g., Hodge et al. 2003, Horst and Moore 2003).

Conversely, a few studies found no effect (or mixed effects) of infrastructure capital on economic growth. For instance, Tatom (1993) found no effect of public capital on productivity growth after making adjustments for a spurious regression problem. Similarly, Garcia-Mila et al. (1996) generated a state-level production function with three forms of public capital—highways, water and sewage systems, and all other public capital—as inputs, and found no evidence of their effect on productivity. Another group of studies considered the spillover effects of transport infrastructure and reported that the development of transport infrastructure in one location may simply relocate economic activity from that location to others, yielding no (or negative) impact on regional economic output (Holtz-Eakin and Schwartz 1995, Chandra and Thompson 2000, Chalermpong 2004). Moreover, some argued that, because the modern transport system already exist in the nation, additional infrastructure investment has little impact on economic output, and the impact, if any, varies across regions (Ewing 2008, Peterson and Jessup 2008).

In addition to the mixed effects of transport infrastructure on economic growth found in previous empirical studies, the direction of the causal relationship remains unclear. Kessides (1996) suggests that simultaneity makes research concerning the impact of transport infrastructure on economic growth tenuous, because economic growth can lead to development of the transport system. Extending the related literature, Fisher (1997) discussed the potential importance of accounting for the possible reverse impact of economic growth on public capital development. The ambiguity about the causal relationship between transport infrastructure and economic growth suggests the need for further research on the economic benefits of investment in transport infrastructure (Nguyen and Tongzon 2010).

Another group of studies has focused on the relationship between transport infrastructure and trade. Many studies have concluded that infrastructure development has a positive effect on trade through lower transport costs. Using a panel of bilateral trade-flow data for 1988-2002, Francois and Manchin (2013) concluded that transport infrastructure not only increases trade volumes, but also increases the probability of trade occurring. Park and Koo (2005) suggested that the impact of telecommunication investment on agricultural trade in importing OECD countries is more important than in exporting countries. In addition, Nordas and Piermartini (2004) suggested that quality of transport infrastructure is an important determinant of trade expansion, and port efficiency is the most crucial among all infrastructure indicators.

Some studies suggested that growth in international trade stimulates public infrastructure development. Since trade is a demand determinant for transport and logistics, growth in international trade will affect their growth (Lee and Rodrigue 2006). Growth in trade between the United States and China has placed greater demands on the U.S. transportation system over the last two decades (Beningo 2008). Wilson et al. (2005) measured the relationship between trade facilitation and trade flows in manufactured goods across 75 countries during 2000-2001. They concluded that differences in the quality of logistics and trade facilitation were related to trade in all regions.

Another strand of literature involves the interaction between foreign exports and economic growth. Most studies concluded that trade benefits economic development by increasing income and employment. For example, countries that trade a higher proportion of their GDP have higher incomes (Frankel and Romer 1999, Irwin and Tervio 2002); exports contribute to economic development via job creation at the state level in the United States (Coughlin and Cartwright 1987, Nishiyama 1997); and Marin (1992) failed to reject the export-led growth hypothesis for the United States, Japan, United Kingdom, and Germany. Conversely, many researchers have found evidence of reverse causality between exports and economic growth. For instance, Leichenko (2000) investigated the causal relationships among exports, employment, and production in U.S. states and regions during 1980-1991 and found bidirectional causality between exports and state economic growth.

Although substantial literature has investigated the causal relationships between public infrastructure and economic growth, trade and economic growth, or public infrastructure and trade, little research has evaluated the interactions among these three closely related factors, except recent studies of developing countries by Khadaroo and Seetanah (2008) and Sahoo and Dash (2012). Khadaroo and Seetanah (2008) applied a vector error correction model to evaluate the impact of public infrastructure (divided into transport and non-transport), trade openness, private capital, and education level of labor on Maruritius' GDP. Their results suggest that all factors had positive impacts on output over 1950–2000, while GDP did not affect public infrastructure capital. Sahoo and Dash (2012) included trade, infrastructure, and labor and capital inputs in the production functions for South Asian countries to evaluate the effects of public infrastructure on output. They concluded that infrastructure development and exports positively affected output and observed a feedback impact from output to infrastructure development.

METHODOLOGY

This study adopts vector autoregression (VAR) models to evaluate the dynamic relationships among economic output, trade, and transport infrastructure. The VAR model has been commonly used when dynamic feedback among evaluated variables is hypothesized (e.g., Cullison 1993, Kamps 2005). An additional advantage is that a *priori* causality directions are not needed between variables (Sturm 1998), which fits the purpose of this study well. In a VAR model, each variable is explained by its own lagged values and the lagged values of the other endogenous variables (Sims 1980).

Before applying the typical VAR model, integration/non-stationarity of the time-series variables is examined through unit root tests, because conventional asymptotic theory is not applicable to hypothesis testing of non-stationary series (Sims et al. 1990). Hence, the Augmented Dickey-Fuller test (ADF, Dickey and Fuller 1979) was employed to test whether each variable is stationary. The ADF test can be presented as:

(1) $$\Delta A_t = \alpha + \rho A_{t-1} + \sum_{i=1}^{n} \varphi \Delta A_{t-i} + \mu_t$$

where A_t is the given time series, Δ is the first difference operator, and μ_t represents an i.i.d. residual term. The optimal lag length, n, is determined by the Schwarz Bayesian criterion (SBC, Schwarz 1978). The null hypothesis of the ADF unit root test is the coefficient of the lagged variable equals zero ($\rho = 0$). Failing to reject the null indicates a unit root exists in the data series. The Phillips-Perron unit root test (PP, Phillips and Perron 1988) was also conducted. This test has a similar null hypothesis, but uses a nonparametric adjustment to the ADF test allowing for dependence and heterogeneity in the residuals.

If ADF and PP unit tests suggest that more than one of the evaluated variables are integrated, a cointegration test must be conducted to determine if the linear combination of those variables is stationary. If cointegration is found among the variables, a vector error correction model (VECM) is appropriate. However, the commonly used cointegration tests developed by Engle and Granger (1987) and Johansen (1988) have size distortion if the variables have roots close to unity but not exact unit roots (Elliott 1998). Moreover, the estimation of the VECM is sensitive to the results of the cointegration test, which likely results in severe over rejections of the null hypothesis (Clarke and Mirza 2006).

The statistical inference issue of unit roots and cointegration tests is addressed in the lag-augmented VAR (LA-VAR) model suggested by Toda and Yamamoto (1995). The LA-VAR model can be estimated without taking differences of the data and applying a Wald test for causality between variables. Most importantly, it is applicable to variables that are stationary and integrated or cointegrated (Kawakami and Doi 2004); hence, avoiding the statistical-inference uncertainty of the cointegration test in the VECM model. A comparison of common methods for detecting Granger non-causality found that the LA-VAR method exhibits consistent performance over a wide range of data-generating processes and performs better in controlling Type I error probability (Clarke and Mirza 2006).

A conventional VAR model of n-vector time series variables, with k lags is written as:

$$(2) \quad V_t = \gamma_0 + \gamma_1 T + \sum_{i=1}^{k} \beta_i V_{t-i} + \varepsilon_t$$

where V_t is an n × 1 vector of series at time t, γ_0 is an n × 1 vector of constants, γ_1 is an n × 1 vector of coefficients, T is a time trend, β_i are n × n matrices of coefficients, and ε_t is an n × 1 vector of i.i.d. innovations (residuals) with n × n covariance matrix ∑. Similar to Khadaroo and Seetanah (2008), six variables were considered in the present study (i.e., n=6), including aggregated economic output (Y), aggregated exports (X), transport infrastructure (H), non-transport public capital (G), private capital (K), and labor (L), to capture the completeness of their interactions in an extended classical economic growth model. The LA-VAR model is generated by adding additional lags up to d_{max} , which is determined by the maximum order of integration in the system. For example, if the maximum order of integration of evaluated variables were one (i.e., taking first differences of the variables to make them stationary over time), d_{max} , and the LA-VAR model would be:

$$(3) \quad V_t = \gamma_0 + \gamma_1 T + \sum_{i=1}^{k+d_{max}} \beta_i V_{t-i} + \varepsilon_t$$

A modified Wald test can be conducted on the first k order of a LA-VAR ($k + d_{max}$) system to test if any given variable is Granger caused by other variables (Granger 1969). The Granger causality test examines whether a variable is predicted by its own past information and the past information of other evaluated variables. Therefore, the null hypothesis imposes the following restriction on equation (3):

$$(4) \quad H_0 = \beta_1 = \beta_2 = \cdots = \beta_k = 0$$

Rejecting the null hypothesis implies that the past information of other variables Granger causes the variable at time *t*.

Although the Granger causality test identifies causal relationships among variables, it cannot show other endogenous variables' responses to a one-time shock to an endogenous variable. Also, as the coefficients of a VAR model are difficult to interpret, an innovation accounting based on a moving average representation (MAR) may be an alternative means to illustrate the dynamic structure of evaluated variables (Sims 1980, Swanson and Granger 1997). An impulse response function generated from the MAR of equation (3) is used to explain how long and to what extent one variable reacts to an exogenous shock to another variable over time. These responses are revealed by the generalized impulse response functions (GIRF) proposed by Koop et al. (1996) and Pesaran and Shin (1998). Unlike the orthogonalized impulse responses that use a Cholesky decomposition to define the contemporary relationships of the variables (Sims 1980), the main advantage of this generalized approach is that the responses are invariant to the ordering of variables (Hurley 2010). The statistical significance of each GIRF is evaluated by 95% confidence intervals using standard error generated by the Monte Carlo method (Lütkepohl 2000). The method generates the non-standard asymptotic distribution of the standard error using 6,000 randomly sampled replications.

DATA

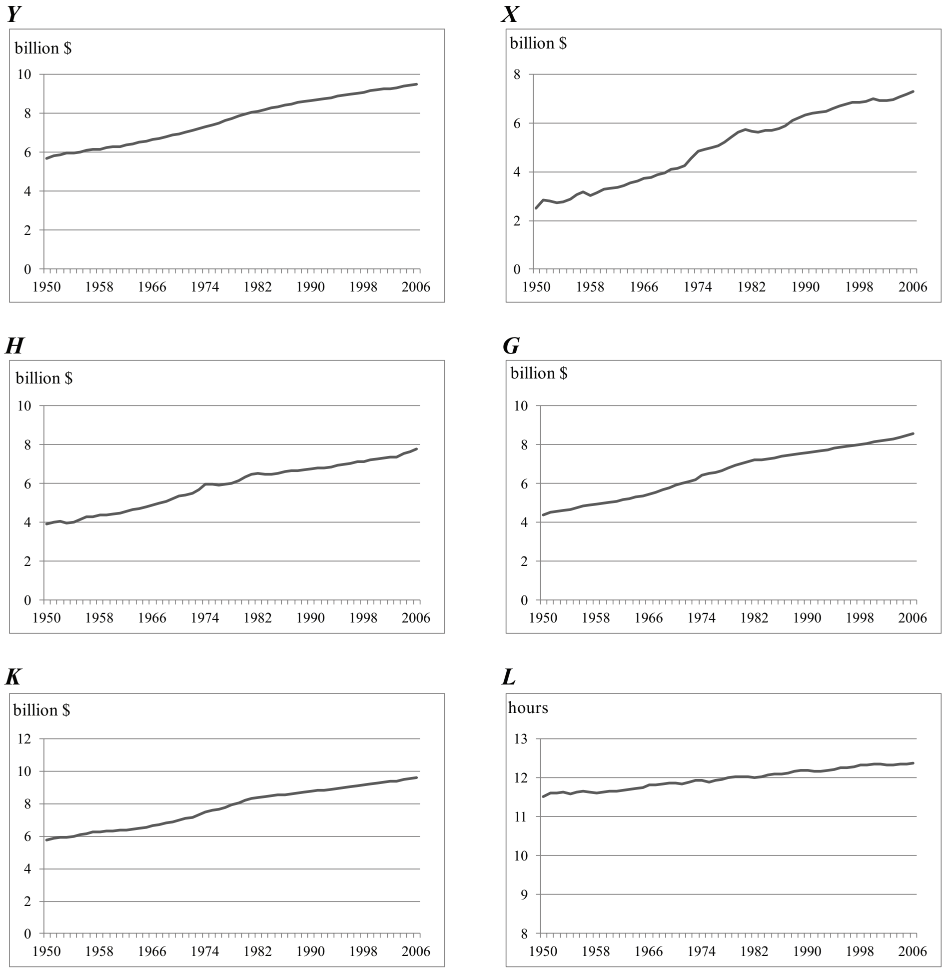
Aggregate economic output (*Y*) is measured by gross domestic product (GDP), while the trade variable (*X*) is measured by the value of exports. The value of exports is selected as a proxy for trade in the analysis since exports are more relevant in the trade and growth literature. Also, Zestos and Tao (2002) suggested the value of exports Granger causes GDP in the United States, but found no evidence of causality from imports to GDP. The transport infrastructure variable (*H*) is measured by the value in current dollars of the net stock of government fixed assets in highways and streets after accounting for depreciation. This study uses highway and street infrastructure to represent transport infrastructure because highway and street infrastructure is the largest single category of public infrastructure capital (Bhatta and Drennan 2003) and is commonly used in the literature when evaluating the economic impact of transportation infrastructure (Baird 2005). The U.S. Bureau of Economic Analysis shows that highway and street infrastructure accounted for 32% of the estimated $9.2 trillion in government fixed assets in 2010, excluding national defense (USBEA 2011).

Non-transport capital (*G*) is measured by the value in current dollars of the net stock of government fixed assets, excluding national defense and highways and streets. Private capital (*K*) is measured by the value in current dollars of private nonresidential fixed assets, consisting of equipment, software, and structures; and labor (*L*) is hours worked by full-time and part-time employees in domestic industry. Annual data for all six variables were obtained for 1950 through 2006 from the U.S. Bureau of Economic Analysis (USBEA 2011). All variables are measured in billions of dollars (except *L*) and converted to logarithms (Figure 2). The observed upward trends suggest the existence of unit roots.

EMPIRICAL RESULTS

The ADF and PP unit root tests are summarized in Table 1. For most data series in levels, both tests fail to reject the null of a unit root with or without trend. Both tests find variables are generally stationary after taking first differences, suggesting the maximum order of integration, d_{max}, is one. The optimal lag length, *k*, suggested by the SBC criterion is also one. Based on d_{max} and the optimal *k*, equation (3) becomes a two-lag LA-VAR. Residuals from the U.S. LA-VAR model are well behaved. The test for normality of the residuals is not rejected (*p*-value of 0.97). Lagrangian multiplier (LM) tests for third and fourth order autocorrelation fail to reject the null of white noise residuals (*p*-values

Figure 2: Plots of the Variables in Nature Logs



Note: Y = aggregate economic output, X = aggregate exports, H = transport infrastructure, G = non-transport public capital, K = private capital, and L = labor.

of 0.30 and 0.18). In addition, the multivariate LM tests for first order autoregressive conditional heteroskedasticity (ARCH) residuals (p-value of 0.15) suggest a constant residual variance.

Table 2 presents the results for the Granger causality tests from the LA-VAR procedure. Highway and street infrastructure capital (H) does not Granger cause economic output (Y). However, evidence suggests a strong causal effect (1% significance level) of economic output on highway and street infrastructure. Non-transport public capital (G) and private capital (K) Granger cause aggregated economic output at 5% and 10% levels, respectively, with no significant causal effects from the other direction. Results suggest both highway and street capital and non-transport infrastructure capital Granger cause exports (X) at the 5% and 10% levels, respectively. This finding is consistent with previous literature that found a positive effect of transport infrastructure on trade (e.g., Limao and Venables 2001, Nordas and Piermartini 2004, Francois and Manchin 2013). However, the reverse causal impacts from exports to highway and street capital or non-transport public infrastructure capital are not observed.

Table 1: Unit Root Test Results

Variable	Levels			
	ADF		PP	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend
Y	-0.65(1)	-0.46	-1.05	-0.53
X	0.04(1)	-2.35 (1)*	-0.62	-1.68
H	-0.35(2)	-1.95(1)	-0.32	-1.50
G	-0.36(1)	-1.42(1)	-0.78	-1.11
K	-0.43(1)	-1.70(1)	-0.57	-1.23
L	-0.49(2)	-3.53(1)**	-1.41	-3.02
	First difference			
	ADF		PP	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend
Y	-5.58(0)***	-5.57(0)***	-5.97***	-5.99***
X	-6.08(1)***	-6.04(1)***	-6.16***	-6.07***
H	-5.55(1)***	-5.5(1)***	-4.99***	-4.95***
G	-3.61(0)***	-3.56(0)**	-3.62***	-3.57**
K	-3.14(0)**	-3.12(0)	-3.09**	-3.07
L	-6.29(1)***	-6.24(1)***	-7.33***	-7.20***

Note: ***, **, and * denote significant at 1%, 5%, and 10%, respectively. Lag lengths included in parentheses are determined based on SBC. *Y* = aggregate economic output, *X* = aggregate exports, *H* = transport infrastructure, *G* = non-transport public capital, *K* = private capital, and *L* = labor.

Table 2: Granger Causality Test Results Based on the Toda-Yamamoto Procedure (1995)

	Y	*X*	*H*	*G*	*K*	*L*
Dependent Variable	Modified Asymptotic Wald Statistics k(1)					
Y	-	0.01	0.57	4.58**	2.90*	0.04
X	0.58	-	5.01**	3.26*	0.10	0.07
H	7.36***	0.16	-	0.01	0.35	2.89*
G	1.4	0.17	5.53**	-	0.21	1.43
K	0.26	0.27	4.71**	1.94	-	0.18
L	0.44	0.62	0.08	0.88	2.09	-

Note: ***, **, and * denote that the null hypothesis of Granger non-causality is rejected at the 1%, 5% and 10% significance levels, respectively. *Y* = aggregate economic output, *X* = aggregate exports, *H* = transport infrastructure, *G* = non-transport public capital, *K* = private capital, and *L* = labor.

A causal relationship is also found between the public infrastructure capital variables—highway and street capital Granger causes non-transport infrastructure at the 5% level. This causal relationship implies that other public infrastructure capital increases when accessibility improves. After the road systems are put in place, development of the non-transport infrastructure (e.g., office buildings, schools, and power lines) follows. A similar causal relationship is observed between highway and street infrastructure and private capital—highway and street infrastructure Granger causes private capital stock at the 5% level. This result suggests that improved accessibility attracts private capital investment, i.e., the crowd-in effect. In addition, a weak causal effect of labor (*L*) on highway and street infrastructure is observed at the 10% level.

The GIRF relating GDP (*Y*), exports (*X*), highway and street capital (*H*), non-transport public capital (*G*), private capital (*K*), and labor (*L*) to each other based on the estimated LA-VAR are depicted in Figure 3. Each panel in the figure presents a variable's response (the bold line) and the corresponding 95% confidence interval (the dash lines) to a one-time shock in another variable over 20 years. The number on the vertical axis represents the change in the evaluated variable (a scale of 0.01 refers to a 1% change), while the number on the horizontal axis is the number of years following one positive shock in another variable.

In panel (a1), the effect of increased exports on economic output is positive in the contemporaneous year (only effects that are significant at the 5% level are discussed onwards unless otherwise indicated). A one-time positive shock in transport infrastructure capital does not create a significant effect on national GDP (a2), while an increase in non-transport public capital positively affects economic output for six years (a3). Panels (a4) and (a5) show that a one-time increase in private capital and labor can also contribute to economic output over three to four years.

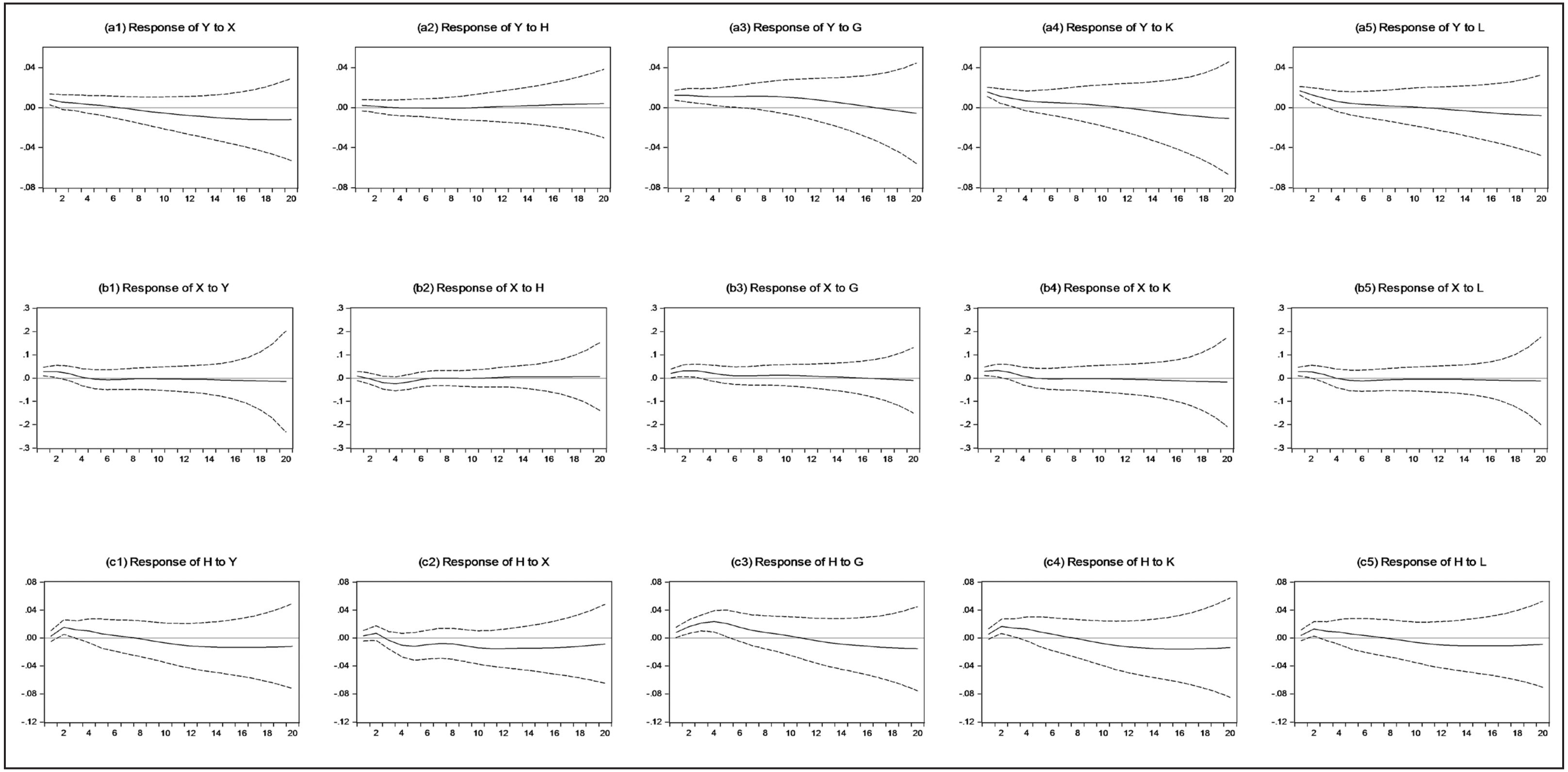
Panel (b1) shows that an increase in aggregated output enhances exports instantaneously and into the following year. An increase in non-transport public capital stimulates national exports over a three-year horizon (b3). Exports also expand instantly when private capital and labor increase (b4 and b5). The GIRF in panel (c1) suggests that a one-time positive shock in aggregated output has a positive lagged effect on government spending on highways and streets, while a one-time expansion in non-transport infrastructure capital creates a positive impact on highway and street infrastructure capital over six years (c3). Similar to the impact of output, a one-time increase in private capital posts a lagged impact on highway and street infrastructure (c4).

The GIRFs for non-transport public infrastructure in panels (d1) through (d5) show that one-time shocks in aggregated output, exports, highways and streets, private capital, and labor all positively affect the formation of non-transport public infrastructure capital. The GIRFs for private capital show that an increase in highway and street capital affects private capital formation in the contemporaneous period in panel (e3), while investment in non-transport public infrastructure capital positively produces a longer impact on private capital in panel (e4). These results provide evidence that public infrastructure investments attract (or crowd-in) private capital development. Also, a one-time expansion in GDP, exports, non-transport infrastructure capital, and private capital elicit positive impacts on labor use (f1, f2, f4, and f5, respectively).

CONCLUSIONS AND POLITICAL IMPLICATIONS

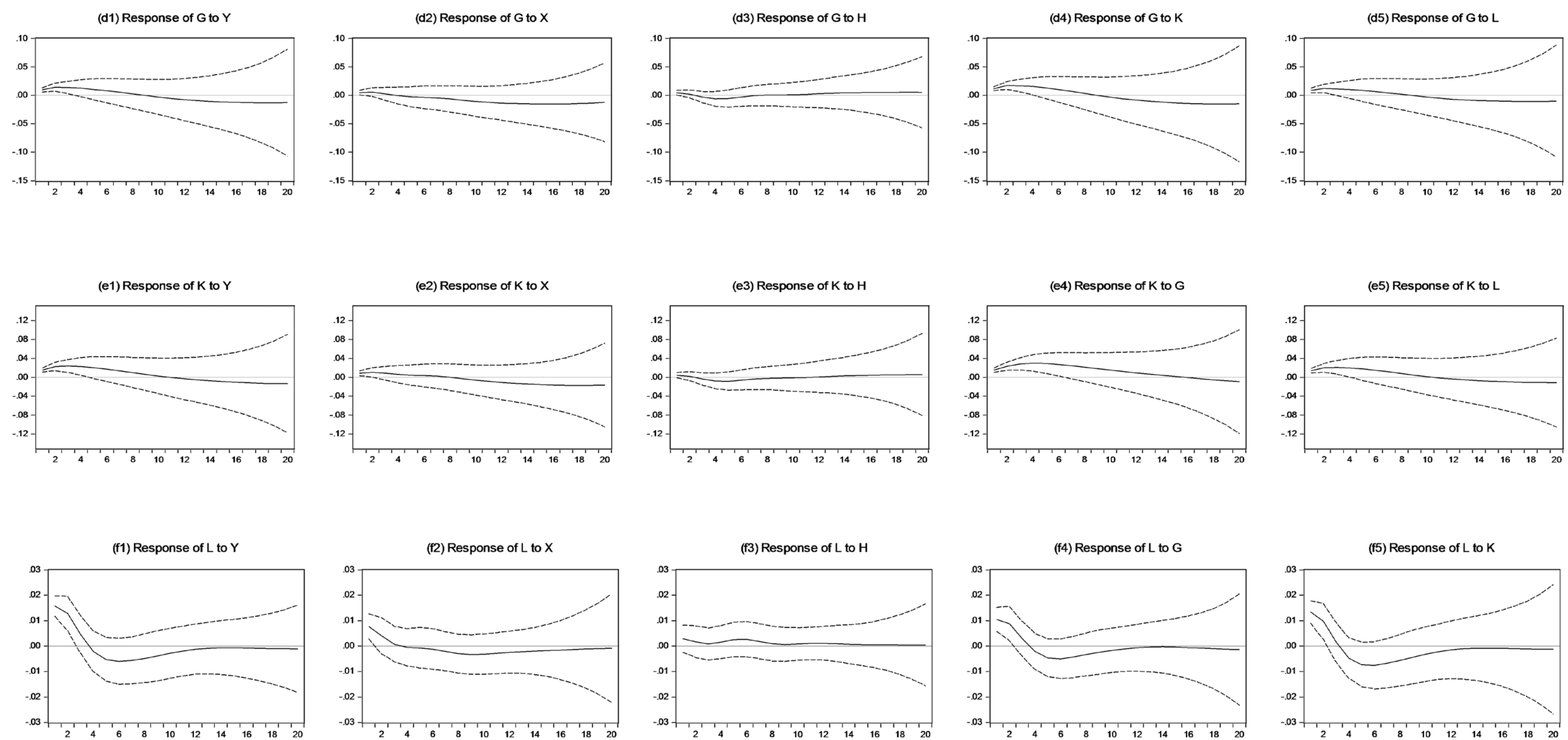
This paper analyzes the dynamic relationships among transport infrastructure, economic output, and exports in the United States using the LA-VAR approach developed by Toda and Yamamoto (1995). The results can be summarized as follows. First, in contrast to some previous studies supporting a direct economic impact of transport infrastructure, results from both Granger causality tests and generalized impulse response functions in our study do not suggest a direct effect of transport infrastructure on aggregated economic output, while causality from economic output to transport infrastructure formation is observed. Second, aggregate non-transport infrastructure capital (e.g., educational structures, power, sewer and water systems, and residential, office and

Figure 3: Generalized Impulse Responses of Each Variable to One Standard Deviation Shock in Another Variable



Note: The number on the vertical axis represents the change of a given variable (a scale of 0.01 refers to a 1% change), while the number on the horizontal axis corresponds to the number of years after the one-time shock. Dash lines represent 95% confidence interval of the response. Y = aggregate economic output, X = aggregate exports, H =transport infrastructure, G = non-transport public capital, K = private capital, and L = labor.

Figure 3: continued



Note: The number on the vertical axis represents the change of a given variable (a scale of 0.01 refers to a 1% change), while the number on the horizontal axis corresponds to the number of years after the one-time shock. Dash lines represent 95% confidence interval of the response. Y = aggregate economic output, X = aggregate exports, H =transport infrastructure, G = non-transport public capital, K = private capital, and L = labor.

commercial structures), excluding national defense, has sustainable positive effects on economic output and exports over several years. Third, evidence shows that both transport and non-transport public infrastructure Granger cause aggregated exports. Fourth, impulse response functions suggest that economic output and exports react to each other immediately. Finally, results suggest that the development of non-transport infrastructure capital creates multiple-year positive impacts on private capital formation and employment.

Similar to Cullison (1993), our findings suggest that expanding transport infrastructure capital, represented by highways and streets, provides relatively short and indirect impacts on aggregated economic output compared to expanding non-transport public infrastructure. The relatively vague economic impact of transport infrastructure capital found in this study is of little surprise, since a developed economy, where substantial highway and street infrastructure already exists, may experience a weaker influence of transport infrastructure investment than observed in developing economies (Talley 1996). Also, public transport infrastructure, such as interstate highways, may only affect the spatial allocation of economic activity, leaving the total net economic impact unaffected (Chandra and Thompson 2000). This finding does not suggest overlooking the contribution of transport infrastructure capital, since both causality tests and impulse response functions imply that improving road systems and enhancing accessibility will affect the formation of both non-transport public infrastructure capital and private capital, which have positive impacts on economic output.

Several policy implications are suggested from the findings of our research. First, as concerns have arisen about the deteriorating 1950s Interstate Highway System and its effects on private sector productivity and the nation's economy, enhancing the nation's transport infrastructure may be crucial to stimulating the stagnant economy. Based on the findings of this study, investment in transport infrastructure will encourage private capital formation and assist in the formation of other public infrastructure, both of which in turn support economic growth. The resulting economic growth will then encourage an increased allocation of resources toward public transport capital formation, perpetuating a cycle of public investment, private investment and economic growth. The recently reauthorized surface transportation bill, MAP-21, is an example of the Obama Administration's intention to stimulate the economy through enhanced public transport infrastructure investment.

Second, the insignificant direct impact of transport infrastructure capital on economic output may imply that the nation's highways and streets are not well managed (e.g., issues of congestion and traffic safety) or maintained, hence, lowering the economic impact of investment in the nation's road systems. Talley (1996) indicated that spatial accessibility and transportation quality-of-service are important when evaluating the economic impact of transport infrastructure investment. Moreover, the road system may not be efficiently utilized, limiting its contribution to the national economy. Thus, along with increasing the transport infrastructure capital stock, greater economic impact may result from policies that better manage and utilize the nation's road system.

Third, given current global economic stagnation and the domestic budget crisis, the results suggest that the U.S. government efficiently allocate scarce budget resources toward crucial public infrastructure formation. Allocating resources to highway and street infrastructure can encourage the cycle of public investment, private investment, and economic growth, while investing in non-transport public infrastructure can provide positive sustainable effects on economic output and exports. As suggested by Garrison and Souleyrette (1996) nearly two decades ago, policy makers should encourage innovations integrating transportation services with improvement in other sectors to enhance and sustain the value of transport infrastructure.

The current study aggregated all highway and street infrastructure into one category. Future research is needed to explore the economic impacts of highway and street infrastructure by disaggregating it into several categories since not all categories would have the same impact on GDP (e.g., interstate highways versus county roads). The economic gains from spending on highway networks linking shipping ports or investment in the state highways with the highest likelihood for increasing local private capital investment can be analyzed, compared, and used to prioritize budget allocations. Also, additional measures of highway infrastructure management, such as government spending on Intelligent Transportation Systems and their operation, or on reducing the hours of congestion on highways, can be included to further evaluate the impact of transportation infrastructure on the national economy.

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