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The role of maritime, land, and air transportation in economic growth: Panel evidence from OECD and non-OECD countries

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Abstract

Accumulated evidence on the positive role of transport infrastructure has been fragmentally reported as an individual type of transport infrastructure—for example, roads, highways, railways, seaports and airports. Relatively few studies have compared the role of different types of transport infrastructure simultaneously. This study attempts to examine the role of various types of transport infrastructure in OECD and non-OECD countries by employing the hybrid production approach that combines macroeconomic growth with supply of and demand for transportation. The panel two-stage least squares method is used to estimate the parameters of economic growth and supply and demand functions, where transportation demand is represented by a principal component. The finding shows stronger significance of maritime transportation in economic growth than air and land transport. However, air and land transport are often irrelevant to or negatively affect economic growth, mostly in developing countries. In addition, the demand for transportation is driven by other social and economic factors apart from prices. Further implications are presented in the concluding remarks. Overall, this paper contributes to providing insights on how transport infrastructure affects economic growth in OCED and non-OECD countries.

Keywords

Transport infrastructure; transportation; transport economics; economic growth; econometrics; OECD.

1. Introduction

It is important for a country to have a high degree of accessibility derived from transport infrastructure, particularly with diminishing trade barriers and the unlocking of new markets (Banister and Berechman, 2001). Accordingly, many nations and economic unions (e.g. the EU and ASEAN) attempt to spend more resources on the provision of transport infrastructure as an essential social and economic asset, as transport infrastructure determines mobility and structural space (Short and Kopp, 2005). For example, the European Commission allocated 76 billion Euros to the construction of transport infrastructure and improvements, including Trans-European Networks (TENs), during the period 2007–2013 based on a common belief that such investment not only eliminates bottlenecks but also increases employment, mobility, accessibility, and gross domestic product (GDP) per capita in the European Union (EU) (European Commission, 2008). Further, academics of the Economic Geography of Transport enthusiastically examined whether provision of transport infrastructure contributes to regional economic growth through better accessibility and lower transport costs (Yu et al., 2012; Lakshmanan, 2011). Indeed, lower transport costs and better accessibility may enable firms to yield higher efficiency, which is derived from spatial agglomeration economies, scale economies, market expansion, and innovation benefits in spatial clusters (Lakshmanan, 2011). More specifically, agglomeration economies can be achieved through a diversity of firms, residents, and workers; on the other hand, external economies of scale can be achieved through density (Chatman and Noland, 2011). Better transport infrastructure not only promotes competitiveness, territorial cohesion, dissemination of knowledge and technology, more competition, and a wider range of choice but also reduces economic disparities (Canning and Bennathan, 2004; Vickerman et al., 1999).

Notwithstanding the novelty of prior studies, most have examined the role of transport infrastructure on economic growth in a single country either at the national or regional level (e.g. USA: Cohen, 2010; Jiwattanakulpaisarn et al., 2010, Berechman et al., 2006, UK: Crafts, 2009, China: Lean et al., 2014; Yu et al., 2012; Hong et al., 2011; Fan & Chan-Kang, 2008, Korea: Park & Seo, 2016, India: Lall, 2007, Portugal: Pereira & Andraz, 2007) or a single economic region (e.g. Europe: Crescenzi & Rodriguez-Pose, 2012; Vickerman et al., 1999). However, utilising observations from a larger number of countries may be more worthwhile for examining how transportation affects economic growth generally across different countries, as long as a possible heterogeneous relationship in each country is adequately controlled. In addition, the use of panel data from a large number of countries enables comparative studies across different groups of countries. For example, when developed and developing countries are compared, greater implications of the more frequent use of transportation in economic development can be obtained. Moreover, the market for transportation—where government supply, firms, and household demand determine transportation use—has tended to be ignored in numerous studies (Hong et al., 2011). Although Lean et al. (2014) adopted the hybrid production approach, this approach simply estimates an individual equation separately without considering instrumental variables to eliminate inconsistency.

In addition, the accumulated evidence for the positive role of transport infrastructure has fragmentally reported limited types of transport infrastructure, such as roads (Crafts, 2009; Fan and Chan-Kang, 2008; Fernald, 1999), highways (Crescenzi and Rodriguez-Pose, 2012; Cohen, 2010; Jiwattanakulpaisarn et al., 2010; Rephann and Isserman, 1994), railways (Banister and Thurstain-Goodwin, 2011; Vickerman et al., 1999), seaports (Park and Seo, 2016; Jaffee, 2015), and airports (Yamaguchi, 2007). Thus, only a few studies have compared the role of different types of transport infrastructure simultaneously. In light of the aforementioned research gaps, this study attempts to examine the role of various types of transport infrastructure in the economic growth of countries belonging to the Organization for Economic Cooperation and Development (OECD) and non-OECD countries. By employing the hybrid production function approach (Röller and Waverman, 2001), this study considers how the amount of the source of economic growth is determined in a market and combines a model of supply and demand with the above-mentioned economic growth model. This approach endogenizes the role of the source of economic growth; its advantage is that it can avoid a bias in the results caused by simultaneity or reverse causation, which could overstate the significance of the source of economic growth. In this study, the level of transportation use is determined by its supply and demand in the transport market.

The remainder of this paper is organized in the following manner. Section 2 reviews prior literature. Section 3 explains the methodology and relevant theories. Section 4 presents the data collection method, variables, and empirical results. Section 5 provides the concluding remarks.

2. Literature review

Identifying the source of economic growth is regarded as the most significant aspect that economists can disentangle (Röller and Waverman, 2001). The emergence of Aschauer's (1989) work stimulated the curiosity of academics in terms of whether public investment in infrastructure is productive for economic growth. Further, the study attracts the attention of governmental bodies due to the assumption that the provision of public infrastructure is an important means to foster economic growth. It is theoretically acceptable that government investment in infrastructure has diverse impacts, ranging from bidding up interest rate and crowding out private investment to improving productivity and spurring economic growth (Wang, 2002). Since the pioneering work of Aschauer (1989), which found that infrastructure makes a rather large contribution to economic output, numerous academics have tested the role of infrastructure investment as an input (Lall, 2007; Otto and Voss, 1996; Evans and Karras, 1993) using various types of infrastructure (e.g. telecommunication: Röller and Waverman, 2001; electricity: Canning and Pedroni, 2004). In addition, numerous studies have found considerable cost saving owing to public investment in various types of infrastructure (Crafts, 2009; Lau & Sin, 1997; Holtz-Eakin, 1994; Aschauer, 1989; Ratner, 1983).

In numerous countries, economic growth is anchored to transport infrastructure, owing to the intensive use of the latter. Decisions related to transport infrastructure are extremely important, as they could last for decades, even centuries (Short and Kopp, 2005). All nations require fully-developed transport infrastructure to compete internationally in global markets (Banister and Berechman, 2001). The impact of transport infrastructure on economic growth is characterised by a typical mechanism. In the short term, it brings about an increase in the number of construction enterprises and, thus, huge job opportunities in construction (Yu et al., 2012). This may spur additional demand for labour in other sectors through the multiplier process, although such benefits would be marginal and short-term (Jiwattanakulpaisarn et al., 2010). Moreover, demand for the movement of goods and services is considerably fostered by investment in infrastructure (Lean et al., 2014). Then, as a direct advantage, economic development is facilitated by time and cost savings for freight and passengers, stimulated by enhanced transportation (McCann, 2005), because it alters the marginal costs of producers of shipping goods and enhances people's mobility. This in turn helps to lower transaction costs on trade (Banister and Berechman, 2001). The freight distributed to the remote and peripheral areas of a country can stimulate rural regions by increasing local employment. In addition, improved accessibility to spatially dispersed markets is considered a key factor in terms of the location of firms and consumers in regional economics (Fujita and Thisse, 2012). *Ceteris paribus*, firms with better accessibility to materials and markets tend to be more competitive, productive, and, thus, successful compared to those with poor accessibility (Vickerman et al., 1999). In certain cases, the relative attractiveness of particular locations might change due to investment in transport infrastructure, which could cause a redistribution of employment among regions (Banister and Berechman, 2001). People would be able to enlarge the geographical scale of their job search and potential workers would be able to become involved in the labour force through the effects of reduction in commuting costs and time (Rietveld, 1994).

Further, investment in transport infrastructure may positively affect economic growth and the development of corresponding regions in the long term. Improved transportation services can serve as a better household amenity, thereby increasing a region's population size by luring in migrants (Jiwattanakulpaisarn et al., 2010). Simultaneously, a reduction in the inventories and storage costs of transport companies results in decreased total cos through higher degrees of flexibility in scheduling, lower variability of transport times, and faster travel speeds due to better transport infrastructure (Shirley & Winston, 2004; Vickerman et al., 1999). Next, augmented infrastructure attracts more foreign direct investment. This may accelerate the corresponding region's industrialisation, which improves production efficiency and labour productivity. Finally, transport-induced economic development, such as a firm's agglomeration, better transport network, easier access to land and labour markets, and environmental quality improvements are achieved (Yu et al., 2012; Banister and Berechman, 2001). As discussed in 'New Growth' literature, the above indirect impacts of an improvement in transport infrastructure can lead to long-run growth and long-term employment (Jiwattanakulpaisarn et al., 2010; Barro, 1990).

Conventionally, a strong correlation exists between the growth in demand for freight and passenger traffic and economic growth (Banister and Berechman, 2001). As such, an extensive body of prior literature has documented the positive effect of transport infrastructure and economic development. Hong et al. (2011) explored the linkage between transport infrastructure and regional economic growth in 31 Chinese provinces from 1998 to 2007. They found that both water and land transport affect economic growth, while the impact of air transport infrastructure on economic growth is weak. Interestingly, they found that land transport infrastructure tends to have a greater influence on economic growth in regions where there is poor land transport infrastructure, whereas water transport infrastructure has a positive impact on economic growth only after the investment level exceeds a threshold. One plausible explanation of this result could be that land is a dominant mode of transport in China, so land transport tends to have a greater impact on economic growth compared to other transport modes. Further, Lall (2007) discovered that transport infrastructure is a substantial determinant of economic growth in India by examining a regionally disaggregated non-linear model of economic growth with data from 1981 to 1996. Interestingly, he found that positive externalities are generated from individual states as well as network expenditure invested by neighbouring states. Moreover, he discovered that the additional benefits of transport infrastructure are higher in lagging states compared to regions which are already well developed. Fernald (1999) empirically uncovered an association between road infrastructure and productivity in 28 US manufacturing industries from 1953 to 1989. Notably, he revealed that if there is an increase in investment in road infrastructure, productivity growth increases in vehicle-intensive industries and decreases in non-vehicle-intensive industries.

Despite numerous empirical studies noting the positive impact of transport infrastructure on economic growth, the evidence of its positive impact remains elusive and inconclusive (Yu et al., 2012; Esfahani and Ramírez, 2003). Crescenzi and Rodriguez-Pose (2012) explored the question of the extent to which transport infrastructure impacted regional growth in the EU between 1990 and 2004 by employing two-way fixed-effect and difference-in-difference GMM panel data regressions; their results revealed that infrastructure endowment is a relatively poor predictor of regional growth in the EU. They argued that the meagre influence of transport infrastructure on regions' economic development raises a question regarding the opportunity cost of additional transport investment across the EU. Further, Rietveld (1989) identified that infrastructure improvement does not necessarily stimulate regional development. It may be inferred that other enablers can play an important role in economic growth. In addition, his study found that development in transport infrastructure lowers transport costs, while the association between infrastructure and private sector growth is interactive. Yu et al. (2012) examined the causal relationship between China's transport infrastructure development and economic growth at the national and regional level by using panel data of 31 provinces over the period 1989–2008. They revealed that transport infrastructure alone is not sufficient to boost economic growth in the underdeveloped areas of China. Further, Hansen and Johansen (2017) studied the wider economic impacts of Norwegian transport infrastructure projects. The study found that projects which are related to leisure trip behaviour merely produce economic impacts, whereas projects related to citizens' commuting patterns create wider economic impacts. Melo et al. (2013) implemented a meta-analysis based on 563 estimates from 33 previous empirical studies. Notably, they discovered that the impact of transport infrastructure differs according to countries and the type of transport mode. Further, they indicated that failure to control unobserved heterogeneity and variables may distort the positive impact of the development of transport infrastructure on the economic development of regions. Holmgren and Merkel (2017) conducted a meta-analysis to examine the association between transport infrastructure and economic growth based on 776 estimates from various prior studies. They found that different modes of transport infrastructure affect certain industries. For example, investment in road transport had a positive impact on the manufacturing and construction industry, while investment in seaport infrastructure affected the agricultural industry was mainly affected by seaport infrastructure investment.

The current study assumes that the additional benefits of transport infrastructure vis-a-vis the economy is lower in OECD countries due to the fact that infrastructure is already developed in these countries compared to that in non-OECD (developing) countries, as Puga (2002) argued. In this regard, certain empirical studies found that at the national level, the highest rates of return to transport infrastructure were found in countries with infrastructure shortages (Canning and Bennathan, 2000), while at the regional level, the benefits of infrastructure are greater in lagging regions (Lall, 2007). Intriguingly, a few studies claimed that expanding transport infrastructure promotes economic development for countries with poor infrastructure endowment, whereas in countries with a high level of transport infrastructure, upgrading or improving the quality of infrastructure would be beneficial for economic growth (Fan and Chan-Kang, 2008; Demurger 1999). Therefore, in OECD countries, where well-developed transport infrastructure and good accessibility are omnipresent, further investment could lead to marginal benefits (Vickerman et al., 1999). On the other hand, non-OECD countries may unambiguously benefit from investment in transport infrastructure, since eliminating bottlenecks can have strong impacts, as developing countries are likely to have more bottlenecks due to lower level of development of transport infrastructure (Blum, 1982).

3. Methodology

The tradition of endogenous growth theories, such as those by Romer (1986) and Barro (1991, 1990), emphasises the role of human capital (Lucas 1998) in promoting economic growth. Accordingly, this study incorporates human capital into the Cobb-Douglas production function, which follows the earlier economic growth literature and commonly employs only physical capital and labour as the factors of production. The use of these two factors is based on early American manufacturing history, when mfachinery and workers were the main factors of production (Douglas, 1976). The role of transportation is then tested as an additional factor in the production function. That is, in our model, economic growth or production of a country *i* at time *t* is explained by the stocks of physical capital (K), labour (L), human capital (H), and transportation (TF), as shown below:

$$\Delta lnY_{it} = \alpha_0 + \alpha_1 lnY_{i,t-1} + \alpha_2 lnK_{it} + \alpha_3 lnL_{it} + \alpha_4 lnH_{it} + \alpha_5 lnTF_{it} + u_{1,it}, \quad (1)$$

where ΔlnY is the growth rate of the level of economic output or income per capita, which is approximated by log differentials; Y_{t-1} is the output per capita in the previous period to account for growth convergence; K includes machinery, equipment, and building; L represents the physical and mental efforts made by humans; H is a collection of intangible attributes of the workforce such as knowledge, skills, and experience; and TF is the level of transportation use or infrastructure. The three different modes of transportation—maritime, land, and air—are used. In addition, α is the coefficient and u is the error term, which can be specified in a particular panel model.

Further, the hybrid production function approach (Röller and Waverman, 2001) considers how the amount of the source of economic growth—for example, TF—is determined in a market and combines a model of supply and demand with the above economic growth model. That is, the role of the source of economic growth is endogenized in this approach. It can also avoid a bias in the results, which may be caused by simultaneity or reverse causation and overstate the significance of the source. In this study, the level of transportation use is determined between its supply and demand in the market for transportation. Then, it is concurrently associated with economic growth, as in (1).

The supply of and demand for transportation can be specified in the following manner. First, the demand for transportation (TD) depends on the price of the transportation service (TP) and income (Y), for example, GDP or GDP per capita. For example, a higher cost of a transportation service reduces its demand, while higher income increases the demand, as people are then able to use a transport service at a higher cost more easily. Since income can be also regarded as economic output, it can capture the effect of increasing population or employment. The time-trend variable (t) is added to reflect social changes that increase the demand over time. The past value of transportation supply is also included.

$$lnTD_{it} = \beta_0 + \beta_1 lnTP_{it} + \beta_2 Y_{it} + \beta_3 lnTS_{it-1} + \beta_4 t + u_{2,it}, \quad (2)$$

where β is the coefficient; β_1 is expected to be negative and can be also interpreted as price elasticity of transportation demand.

Second, the supply of transportation (TS) as a public infrastructure or investment is determined by the government decision to invest in transportation services. Their decisions are first based on the price of the transportation service (TP), since the government is expected to increase investments when it observes an increasing price due to the shortage of supply. Moreover, other fiscal and geographical factors such as the indebtedness of the government (DB) and the size of geographical area of the country (AR) may affect the amount of investment. For example, a more indebted government is less likely to increase transportation investment, while the larger geographical size of a country requires a greater supply of infrastructure. Moreover, the past value of demand is added to control for demand-induced transportation supply (Noland, 2001). Then, the supply function is specified as

$$lnTS_{it} = \gamma_0 + \gamma_1 lnTP_{it} + \gamma_2 DB_{it} + \gamma_3 lnAR_i + \gamma_4 lnTD_{it-1} + u_{3,it}, \quad (3)$$

where γ is the coefficient; γ_1 can be defined as the transportation supply elasticity and is expected to be positive. Finally, the system of hybrid production—(1), (2), and (3)—is completed.

Each equation in the system could be individually estimated, namely the isolated approach; however, the estimates in the economic growth model in (1) will not be consistent if correlation exists between explanatory variables and the error term—that is, endogeneity. Alternatively, three equations can be reduced into a single equation, assuming that the market for transportation clears and, thus, only equilibrium supply and demand are observed ($TF_{it} = TD_{it} = TS_{it}$). However, the role of transportation infrastructure, which is the focus of this study, cannot be easily revealed. Therefore, instrumental variable (IV) methods are adopted to estimate the system of hybrid production. For example, the two-stage least squares (2SLS) estimation method can provide consistent estimators, even when some of the explanatory variables are not exogeneous in an equation. The first stage of the 2SLS method regresses each of the endogenous variables (TFs and TP) on all exogeneous variables (Y_{t-1}, K, L, H, t, DB, and AR) in the system and additional instruments. Thereafter, in the second stage, the economic growth model is estimated with the estimated transportation variables from the first stage. Subsequently, the equations of transportation supply and demand, (2) and (3), can be estimated using the same method. Although the 2SLS method theoretically produces consistent estimates, its estimators are inherently biased and usually impose the homoskedasticity assumption. The generalised method of moments (Hansen 1982, GMM), another IV method more commonly used for system estimation, is known to work better with heteroskedasticity in the general overidentified case. Each equation is identified as the number of excluded instruments and is at least equal to that of endogenous variables. However, the appropriate IVs are practically difficult to find in macroeconomic data, as they must have a relationship only with the IVs and not with the dependent variable. Therefore, this study presents the results obtained with OLS, 2SLS, and GMM estimation of the main model in (1).

In addition, panel vector autoregression (VAR) Granger causality tests are employed to further verify causation between economic growth and transportation, as used in Pradhan and Bagchi (2013) and Arvin et al. (2015). For example, the significance of δ_{11} in the following panel VAR system indicates the role of transportation in economic growth. δ_{21} indicates reverse causality.

$$\Delta lnY_{it} = \delta_{10} + \delta_{11} lnTF_{it-1} + \delta_{12} lnY_{i,t-1} + \delta_{13} lnK_{it} + \delta_{14} lnL_{it} + \delta_{15} lnH_{it} + u_{1,it}, and \quad (4)$$

$$lnTF_{it} = \delta_{20} + \delta_{21} \Delta lnY_{it-1} + \delta_{22} lnY_{i,t-1} + \delta_{23} lnK_{it} + \delta_{24} lnL_{it} + \delta_{25} lnH_{it} + u_{2,it}.$$

On the other hand, unlike the supply of transportation which can be measured by public infrastructure or investment, the demand for transportation is usually measured by usage data from different modes of transportation. However, their units of measurement may not be easily comparable. For example, the twenty-foot equivalent unit (TEU) or tonnage in maritime transport cannot be aggregated with metric ton-kilometres, which are commonly used in land or air transport. A possible solution could be to utilise a factor that best explains the variation of demand for all three types of transportation.

Principal component analysis (PCA) builds a set of uncorrelated variables—that is, principal components—which reflect the variation of a set of original variables that may be correlated. Suppose that **x** is a vector of p random variables (x_1, ..., x_p) and $\mathbf{a_1}$ is a vector of p constants. The first task in the PCA is to identify their linear combination ($\mathbf{a_1}'\mathbf{x}$) that has maximum variance. Then, it another linear combination (e.g. $\mathbf{a_2}'\mathbf{x}$) is identified that has maximum variance, subject to being uncorrelated with $\mathbf{a_1}'\mathbf{x}$. This process continues until a sufficiently high number (≤ p) of principal components, which captures as much variation, is achieved. That is, the first principal component, which accounts for the largest possible variation of all three transportation usage variables (p = 3), can be regarded as the representative demand variable for transportation (TD). Note that this demand variable represents the general demand for transportation not the demand for individual modes. More technical details related to PCA are explained in Jolliffe (2002), while numerus prior studies pertaining to the role of transport infrastructure on economic growth have employed PCA due to its advantage (Crescenzi and Rodriguez-Pose, 2012).

3.1. Data

The main data set consists of yearly observations of economic and transportation data of 34 countries, 17 OECD members, and 17 non-member countries between 1996 and 2014. The sample countries are selected from the countries listed on the OECD database, which also contains the data of non-members if they are available and internationally comparable (OECD, 2016). Member or non-member countries which have missing transportation data are omitted. OECD member countries include developed countries and non-members include developing countries. It must be noted that the membership of the OECD generally requires like-mindedness in terms of sharing the values of the existing countries—for example, market-based economy, democratic principles, good governance, rule of law, and human rights (OECD, 2004)—and, therefore, it does not entirely depend on economic performance.

<Table 1 around here>

Economic production or income (Y) is represented by GDP per capita (at 2005 dollar prices). The stock of physical capital (K), labour (L), and human capital (H) is approximated by fixed capital formation per capita (investment in fixed asset, 2005 dollar prices), population (log), and the number of college graduates per 100,000 people, respectively. L and H are the quantity and the quality of the workforce. On the other hand, maritime transport (TFM) is measured by throughput in twenty-foot equivalent units, and air and land transport (TFL and TFA) is measured by freight transported by each mode in million ton-kilometres. Note that transport data are used instead of infrastructure data due to data limitations. Transportation price (TP) is approximated by dollar cost to export per TEU, which includes inland transportation cost. Government indebtedness (DB) is represented by the total government debt as a percentage of GDP. Geographical area (AR) is represented in square kilometres (km^2). For the analysis of transportation demand and supply, the first principal component of transportation demand and transportation infrastructure investment are used, respectively. Additional instrumental variables include the current level of output per capita, gross fixed capital formation as a percentage of GDP, and the time-trend variable as specified in Röller and Waverman (2001). The panel is unbalanced because of missing data in certain variables. The data is obtained from the databases of the United Nations (UN) Conference on Trade and Development (UNCTAD), the World Integrated Trade Solution (WITS) of the World Bank, OECD, and the Food and Agriculture Organization of the UN (FAO).

4. Empirical results

Although the OECD membership does not necessarily imply a high level or a large share of world GDP, trade, and population, on average, OECD (developed) countries are wealthier than non-OECD (developing) countries by almost nine times in terms of GDP per capita, despite having generally smaller geographical areas and population (Table 2). However, they have a higher level of debt, and the degree of physical and human capital formation is much larger. In terms of transportation infrastructure and use, developed countries employ sea and air transport for freight, while developing countries rely more on land transport. Transportation prices are similar across the two groups of countries, on average, but the variation is larger in developing countries. On the other hand, developing countries show faster economic growth, larger population, weaker accumulation of capital, and slightly lower quality of labour force. Note that GDP per capita (Y) contains a unit root in panel Augmented Dickey-Fuller (ADF) tests, unlike the other variables, but spurious regression will not be an issue since they will be used as either dependent or explanatory variables in each model specification. Further, it is known that the estimators and test statistics in panel models are asymptotically normally distributed even with a unit root (Baltagi, 2013).

<Table 2 around here>

The correlation between economic growth (ΔlnY) and the other variables is summarised in Panel A of Table 3. The two groups show a distinctive contrast in the sign and degree of correlation, except the correlation between economic growth (i.e. growth rate of GDP per capita) and physical capital (K). This necessitates a separate analysis of the two groups. In general, the relationship between GDP and each transportation mode is stronger in developed countries than in developing countries. Moreover, maritime and air transportation show a positive correlation with economic growth in developed countries but have a negative correlation in developing countries. This implies that promoting the stronger and more positive links between capital-intensive transportation modes and economic production is vital for developing countries to become developed countries. However, note that correlation does not control for factors other than the two variables.

<Table 3 around here>

On the other hand, the correlation between land transportation and maritime and air transportation is much weaker in developing countries than in developed countries (Panel B of Table 3). This may be the result of a relative delay in constructing expensive maritime and air transportation infrastructure in developing countries. Moreover, this may imply the low level of multimodal transport services in these countries. Simultaneously, the stronger relationship between maritime and air transportation in developing countries could imply that their development is likely to proceed in the same direction.

The principal component of transportation demand is generated from three transportation variables (Table 4). Although a maximum of three principal components can be generated from the PCA, the size of the eigenvalues of the principal components, only one of them being larger than one, supports the use of only the first principal component. This single principal component explains almost 70% of variation of the transportation variables alone and, thus, can be regarded as representative.

<Table 4 around here>

The economic growth model in (1) is first estimated independently (Panel A of Table 5) without incorporating the supply-demand relationship in the hybrid production function approach in (2) and (3). The results from both the fixed-effect and random-effect models are both presented since the Hausman tests do not meet asymptotic assumption, although the random-effect model is preferred for developing countries.

<Table 5 around here>

The fixed-effect model adopts country-specific intercepts that reflect unobservable and time-invariant country-specific factors. First, when all sample countries are used, only maritime transport has a significant positive effect on economic growth, which contrasts with the insignificant effects of air and land transport. This may indicate the role of maritime transport in facilitating domestic economic activities or the openness of the economy, which could be important in economic growth. In the same results, population (L) has a marginally negative impact on economic growth. This may indicate that an excessively large population leads to a congestion in sourcing and distributing economic resources across the economy. Physical and human capital (K and H) have a significant positive impact. Second, in developed countries, both maritime and land transport significantly facilitate economic growth; the accumulation of physical capital is another driving force. However, the quantity and quality of labour (L and H) do not play a significant role. Last, in developing countries, only maritime transport has a positive and significant impact among different transport modes. Air and land transport have negative signs, although these are insignificant. Population (L) has a significant negative impact, but the quality of the workforce (H) has a significant positive impact on economic growth.

In sum, the fixed-effect models indicate that the role of maritime transportation is universal and vital in economic growth. However, the roles of air and land transport are not strongly associated with economic development. The positive role of physical capital is confirmed, and human capital is also important in developing countries. On the other hand, a concentrated population actually hinders the economic growth of developing countries until it becomes irrelevant when they are sufficiently developed.

The random-effect model assumes that the differences between the countries which are not explained by the explanatory variables are randomly determined. First, with all sample countries, the random-effect model shows that maritime transport has significant and positive impacts on economic growth. However, land transportation has marginally negative effects. Unlike the fixed-effect models, population and workforce quality are not significant, but physical capital has a positive impact just like the fixed-effect models. Second, in the developed countries, only maritime transport significantly affects economic growth. The effects of air and land transport are also positive but not significant. Again, it is evident that the accumulation of physical capital is important but quantity or quality of workforce is not once a country becomes developed. Last, maritime transport has a positive and significant effect on the economic growth of developing countries, but air and land transportation have a negative and marginally significant impact, which contrasts with developed countries. This implies that the required resources to keep up with an increase in the number of goods transported by air and land could be a burden on the growth of developing countries. However, maritime transportation is more directly related to cross-border economic activities and, thus, is less of a burden to the rest of the economy and more of a boost even for developing countries. Further, population (L) is negative but its quality (H) has a significant positive impact on economic growth; it has irrelevance for developed countries.

Therefore, the significant role of maritime transport is evident across developed and developing countries, but air and land transport does not affect economic growth in developed countries or even hinder it as in developing countries. The negative effects of labour concentration or population, mostly observed in developing countries, can be explained similarly. Among other economic variables, physical capital is revealed to play a consistently significant positive role. However, the positive impact of human capital is only evident in developing countries.

<Table 6 around here>

The hybrid production function approach (Table 6) further considers the supply and demand relationship, (2) and (3), using the 2SLS and GMM methods with IVs. In the 2SLS fixed-effect model, the significance of maritime transport is observed in the samples with all countries, including the developed countries. However, the contribution of transportation seems weak in developing countries. The GMM method also provides the similar results. Note that the results with the fixed-effect model may not be ideal since the significance of economic variables is weaker than other estimated models.

The random-effect model provides improvement in the overall fitness of the model in terms of the significance of the economic and transportation variables. When both groups are estimated together, maritime transportation appears to lose its significance, while the impact of air and land transportation becomes significantly negative and positive, respectively. However, when developed and developing countries are estimated separately, the positive effect of maritime transport appears in each group, while the impact of air and land transport becomes insignificant in developing countries. The negative effect of population (L) is evident in both groups, but the impact of physical capital is evident only in developed countries and that of human capital only in developing countries. Overall, the IV estimation of the hybrid production function, either by 2SLS (fixed or random) or by GMM, provides fairly similar results, particularly in terms of the role of transportation. Further, the results from the hybrid production function approach are consistent with the findings from the isolated production function obtained by employing OLS methods, presented in Table 5.

In summary, the economic growth models, both with and without the hybrid production approach, yielded the following findings:

- Maritime transport is important in facilitating economic growth.
- Air and land transport are often irrelevant to or negatively affect economic growth, mostly in developing countries.
- Physical capital is extremely important in the economic growth of developed countries.

- The size of the population negatively affects the economic growth of developing countries.
- Human capital promotes economic growth, but only in developing countries.

One of the main findings from the endogenous growth model is the importance of maritime transportation in economic growth. However, reverse causation may exist, that is, stronger economic growth leads to greater use of maritime transportation rather than maritime transportation promoting a higher growth rate. Thus, as a robustness test, the panel vector-autoregressive (VAR) Granger causality test (Abrigo and Love, 2015) is employed to further examine whether the current values of one variable are explained by the lagged values of the other variables. First, the causation between economic growth and three modes of transportation including maritime are concurrently tested in a system of four equations (3TF in Table 7). Then, each paring between economic growth and each transportation mode is tested (1TF in Table 7). Economic variables in (1) are also used as additional exogenous variables with lag 1. This can also help restrict the number of equations and parameters in panel VAR models while focusing on the interaction between economic growth and transportation. The results with the entire sample confirm the causality between maritime transport and economic growth as well as the collective significance of all three modes of transportation in economic growth. Moreover, it shows the relative importance of maritime and land transport over air transport. The weak causation revealed in both sub-sample groups could be because panel VAR models consume a relatively higher degree of freedom in smaller samples.

<*Table 7 around here*>

On the other hand, the demand and supply functions for transportation can also provide valuable insights into how the market for transportation works in general. First, the transportation demand function in (2) is separately estimated using the 2SLS method to investigate the relationship between the demand for transportation and other factors that are expected to determine the quantity demanded. The principal component of transportation demand is adopted as a representative demand variable. Despite the positive relationship between transportation demand and income, the negative impact of price is not statistically confirmed as in Panel A of Table 8. This implies that the demand for transportation is driven by social and economic factors other than price. Alternatively, this may be because the principal component of demand has a weakened relationship with a proxy variable for transportation price. Note that it is preferable to use random-effect model with the Hausman test.

<*Table 8 around here*>

Subsequently, the transportation supply function in (3) is also estimated using the 2SLS method using government transportation infrastructure investment as the dependent variable. Although the Hausman test favours the fixed-effect model, which excludes geographical area, the results of both the fixed- and random-effect models are presented in Panel B of Table 8. The results indicate that the larger geographical size of a country increases transportation supply, as expected. Further, the higher government indebtedness reduces the percentage of GDP invested in transportation infrastructure more strongly in developing countries. One interesting finding is the negative link between the cost of transportation and transportation infrastructure investment in most of the cases, unlike in typical supply functions. This shows that the lower cost of transportation is associated with more active investment in transport infrastructure.

5. Concluding remarks

Although numerous studies have investigated the role of transport infrastructure on economic growth in one country either at the national or regional levels, the comparison of the role of transport infrastructure in OECD and non-OECD countries has been ignored. By filling this gap, this paper contributes to existing research by providing certain insights into how transport infrastructure affects economic growth generally across different countries, as long as a possible heterogeneous relationship in each country is adequately controlled with the use of panel data. Accordingly, this study effectively responds to Banister and Berechman (2001) by indicating that more than a national-level analysis is required in revealing the role of transport infrastructure on economic growth.

Firstly, the main finding from the empirical analysis is the significance of maritime transportation in economic growth. This is also confirmed in a dynamic causality test. The use of TEU might be an adequate approximation of maritime infrastructure. A viable reason for this result might lie in the nature of maritime transport. Maritime transport is a dominant mode of international (or often domestic) transport for high-volume inter-regional cargoes using deep sea shipping (or often short-sea shipping). Indeed, it is the cheapest means to transport goods between continents, accounting for over 90% of international trade in terms of cargo volumes (Stopford, 2009). The empirical study uncovered that doubling transport cost for international trade results in the halving of the economic growth rate and also found that landlocked countries tend to suffer vast cost disadvantages because of higher inland transport costs from the ports of adjacent countries (Radelet and Sachs, 1998). Interestingly, the finding of the study confirms that most countries, regardless of whether advanced or developing, can achieve economic growth through maritime transport (infrastructure). The result implies that major seaports in both OECD and non-OECD economies have played a crucial role in global trade, processing natural resources for export and serving as a centre of value-adding manufacturing. This finding corroborates the argument of the location theory (Puga, 2002) that better transport infrastructure increases firms' profits through cheaper transport costs and helps expand new markets by means of a lower trade cost.

Secondly, the finding indicates that air and land transport may often be irrelevant to or negatively affect economic growth, mostly in developing countries. Occasionally, in developing countries, increasing air and land transportation may deter economic development. These results could be attributed to the fact that the use of million ton-kilometres is a poor approximation of the air and land infrastructure stock, or that poorer variable specification results in the negative impact of transportation on economic growth. The evidence from China (Lean et al., 2014) shows the negative impact of air transportation on economic growth, although land transportation positively affects economic growth in Hong et al. (2011). The difference could be from the infrastructure data adopted in their study, which may not fully reflect the negativity arising from the excessive use of infrastructure. A plausible interpretation of the negative impact of air and land transportation in developing countries would be that it is insufficient to create growth by merely enhancing accessibility, which translates into higher cargo volumes and reduced travel time (Banister and Berechman, 2001). In developing countries, air and land transport infrastructure may not always be most effectively utilized due to the lack of supporting or auxiliary services; thus, there is a much smaller benefit from investment in air and land transport infrastructure (Hulten, 1996). Moreover, in developing countries, other sets of conditions such as geography, suitable human capital, political situation, governance, management, innovation, information and control system, and level of technology are varied compared to those in developed countries and this might cause a difference in economic growth (Straub, 2011; Banister and Berechman, 2001; Demurger, 2001). Notably, the result of this study supports Short and Kopp's (2005) arguments that the return rate of such investment may depend on the country's development stage or, more specifically, on the gap between the long-run transport infrastructure endowment per capital of the economy and its current value. Another possible interpretation of the result would be that the quality of the infrastructure rather than its quantity may be deeply related to economic growth, as indicated by Banister and Berechman (2001). In similar vein, Vickerman et al. (1999) noted that only when transport infrastructure considerably eliminates bottlenecks can the positive impacts be observed.

Thirdly, physical capital plays an important role in the economic growth of developed countries, while labour concentration negatively affects the economic growth of developing countries. This finding is rather counter-intuitive because a few studies argued that densification of people, cities and industrial clusters increase external agglomeration economies (Chatman and Noland, 2011). A conceivable explanation for this is that transport infrastructure might be a missing link in the association between labour concentration and economic growth. For example, certain developing countries already have spatial densification, but due to a lack of the appropriate level of infrastructure and major traffic congestion, it is difficult to achieve reduced travel time for people and cargoes, which may end up hindering economic growth. In this regard, Chatman and Noland (2011) indicated that in the absence of sophisticated transport infrastructure, densification is a mere redistribution of growth from less-dense to more-dense areas; thus, it barely leads to any external benefits.

Fourthly, the findings of this study indicate that the demand for transportation is driven by social and economic factors other than prices. This finding is somewhat counter-intuitive, as it is well-known in transport economics that lower transport costs lead to a greater amount of cargo being transported (or manufactured) due to the total costs of goods being lower (Cowei, 2010). A possible explanation here might be that the causation can be reversed, thereby implying that other social and economic factors such as higher GDP and changing people's consuming patterns leads to a higher level of transport demand, as transport demand is a derived demand.

Finally, this study reveals that the larger geographical size of a country increases transport supply. This result is taken for granted, as the government spending on transport infrastructure is usually spread across the entire country so that an equality of standards among regions can be maintained and a larger population can benefit from it (Alesina and Wacziarg, 1998). In addition, the higher government indebtedness reduces the percentage of GDP invested in transport infrastructure more strongly in developing countries. When the level of government indebtedness is high, there are difficulties in the implementation of government policies owing to a drop in tax revenue and low cash flow; thus, the government tends to reduce its public capital investment by postponing or cancelling projects (Lavee et al., 2011). Developing countries might have a far larger number of areas (e.g. schools, hospitals, roads, bridges, etc.) that require government spending, because their infrastructure development level is still at an early stage. Accordingly, in developing countries, spending that is intended for transport infrastructure might actually be spent on other areas when the government faces a high level of indebtedness. As such, Lavee et al. (2011) indicated that such reduction in transport infrastructure investment may be detrimental to the long-term economic growth. Another finding of this study is that the negative impact of the cost of transportation on transport infrastructure investment is common. In other words, this implies that the low cost of transport is linked to more active investment in transport infrastructure. A potential interpretation of this could be that cheap transport results in greater use of transport infrastructure. Then, such frequent use might need more spending on maintenance or greater transport demand for new construction of existing transport infrastructure.

Despite this study's implications, there is room for further research. Firstly, future study could take into account transport infrastructure quality as an independent variable. Secondly, future research could estimate the synergetic effects of various types of transport infrastructure, as transport infrastructure is a multidimensional phenomenon with synergetic effects at the theoretical level (Rietveld, 1989). Finally, this study only focuses on the comparison between OECD and non-OECD countries; thus, designing an adequate policy at the country level must rely on country-specific studies.

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