Article

Impact of Infrastructure Connectivity and Human Capital in the Trade-Growth Nexus in ASEAN Countries

Phoutvichay LINSOMPHOU*
Jean-Claude MASWANA**
Kazuo INABA***

ABSTRACT

While the ASEAN has pursued functioning regional connectivity, the master plan on ASEAN connectivity (MPAC) 2025 has addressed bottlenecks of cross-border trade routes and leveraged supply chain efficiency in human resource development. This paper intends to analyze the impact of infrastructure connectivity and human capital in the trade-growth nexus, over the period of 2006–2019. Based on Grossman and Helpman (1991; 1994), the estimated results imply that the significant infrastructure of liner shipping connectivity bolsters economic development. Human capital is found mostly calibrating skill technology frontier for trade operation to mechanize economic growth in ASEAN countries. The findings imply that infrastructure connectivity in variations of the logistics may be context-dependent and enhanced by reliable skills in trade-led growth, while the leading time to the export process (delays constrained and less frequent connectivity) could impede economic growth. Empirically, ASEAN's economic growth might depend on fundamental differences driven by varying types of trade and infrastructure connectivity endowments. Calibrated human capital in technology could play an important role in the leveraged transitional technology and soft-skills policy across the logistics industry could work in supply chain efficiently. The synergy impacts of inter-modal connectivity may shape the trade-growth nexus sufficiently to integrate ASEAN economies into international markets.

Keywords: *Infrastructure Connectivity, Human Capital, Trade, Economic Growth, ASEAN.*

*Corresponding Author, E-mail address: Phoutvichay, Ritsumeikan University (phoutvichayaec@gmail.com);
**Maswana, Ritsumeikan University (maswana@fc.ritsumei.ac.jp);
***Inaba, Ritsumeikan Univiersity (inabak@ec.ritsumei.ac.jp).

1. Introduction

The Association of Southeast Asian Nations (ASEAN) is recorded as equivalent to 30% of the world GDP (approximately trade-based 2.5 trillion USD) and 676 million of population (ASEAN, 2024). The region's connectivity as a coherent element of the ASEAN Economic Community (AEC) 2015 has contributed to the acceleration of trade performance and regional economic growth. As adopted at the $28^{th}/29^{th}$ ASEAN Summit 2016, the Master Plan on ASEAN Connectivity (MPAC) 2025 aims to function seamlessly and comprehensively in the market base across connected and integrated ASEAN countries (ASEAN Secretariat, 2016).

Infrastructure connectivity is empirically affirmed as a fundamental of trade and economic development. Investing in infrastructure across the logistics industry affects not only the enhancement of physical connectivity but also the smooth trade of goods and services through supply chains' facilitation and trade cost reduction (Yu, 2017; Munim and Schramm, 2018; Katrakylidis and Madas, 2019; Del Rosal and Moura, 2022). The logistics improvement from maritime trade to landlocked economies is essential to regional infrastructure connectivity for trade efficiency, which subsequently affects economic growth. Saidi et al. (2018) and Wang et al. (2020) indicate that infrastructure connectivity has pivotal links to landlocked economies. These transport infrastructure's potentiality may evolve spatially in diffusion effects (spreading technological changes in knowledge spillovers), thus stimulate higher productivity in initial trade-led growth and market expansion in regional economic integration.

Lun and Hoffmann (2016) and Fugazza and Hoffmann (2017) stress that the trade advantage in ASEAN is actively driven by logistics connectivity. They reveal the potentiality of shipping connectivity and trade relativity (intra-and extra-trade flows) in promoting the region's economic integration and international trade. Essentially, the current emerging urbanization and vibrant e-commerce have dramatically changed the demands of investments and flows of goods and services. These changes show a remarkable shift compared to the past patterns because only raw materials and natural resources are mainly shipped along developing countries for the maritime economy. Thus, ASEAN logistics competitiveness keeps its effective role in sustaining manufacturing, trade facilitation, and mobility of capital and labour, and helps trade creation to diversify economic activities. As fundamentals of infrastructure connectivity (MPAC 2025; UNESCAP, 2023; UNCTAD, 2024), liner shipping connectivity may be firmly classified as geographical segments that incorporate technology to mechanize the infrastructure of the logistics industry (Jouili, 2019), and this connectivity links the coastal with landlocked economies in facilitating prioritized trade routes to enhance economic growth. Márquez-Ramos et al. (2011) indicate that the liner shipping connectivity through logistics endowments induces trade connection of regional economies.

Although previous studies in ASEAN have indicated essential determinants of liner shipping connectivity (Brooks, 2016; Jouili, 2019), their discussion of dominant seaports and connectivity components on international trade (applied container port traffic) has not included all ASEAN members (Reza, 2015). In addition, the literature that deals with spatial contexts, causality, and path (structural equation) analysis, have focused only on a single aspect of the infrastructure such as traditional transportation and energy (Maparu and Mazumder, 2017; Saidi et al., 2018). These clue multiple aspects should be directed to the mechanism of infrastructure connectivity and human capital. Research questions of this study are: (1). Do variations in infrastructure connectivity and human capital across ASEAN countries affect their trade-growth performance? and (2). How do institutions play important roles in shaping the trade-growth nexus in ASEAN?

With the improvement of trade facilitation, infrastructure connectivity is critically embodied in the regional economy. ASEAN has still faced a low level of logistics development, while ASEAN's integration and connection to market access are perpetually needed. Meanwhile, developing economies have low-emerged diffusion of infrastructure and lack of a mechanism in human resources for connectivity to boost the trade-growth nexus. To fill the multifaceted connectivity and inter-modal integration across ASEAN economies, this study examines the impact of infrastructure connectivity and human capital in the trade-growth nexus in ASEAN countries. The study also explores how various aspects of connectivity impact economic growth.

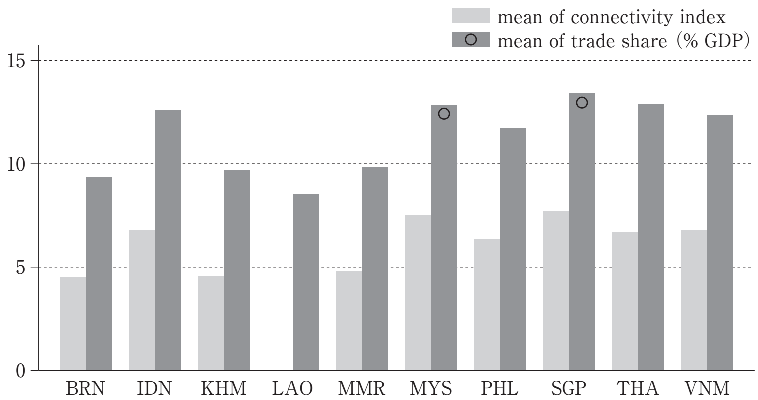
The remainder of the paper is as follows: Section 2 provides the background of the ASEAN. Section 3 reviews previous studies. Section 4 delves into the model specification, data, and methodology. Section 5 discusses those empirical results and findings. Section 6 is conclusion with some policy implications.

2. The Background of ASEAN Connectivity

The ASEAN community is currently undergoing regional development and production networks with huge demands in the investment of infrastructure connectivity. In the Asia-Pacific region, the Global Infrastructure Hub (GIH) assesses that investment in connecting infrastructure will be more than double in ten years, an average of $2.5 trillion per year in 2020, and the accumulated total investment would be approximately $26 trillion by 2030 (ADB, 2023). Through developing infrastructure connectivity that helps to overcome specific bottlenecks and impediments in major trade routes and trade costs, the efficiency of the logistics industry works as an attached mechanism to ensure the speed in time to trade and reliability of supply chains in the ASEAN economy. The frequent flow of goods and services at crossing borders and ports (land and sea, even linking to airfreight) are identified as key choke-points to trade and investment. While regional challenges remain in insufficient investment despite large needs in infrastructure connectivity and lack of human capital in workforce skills and trained experts mobility, the implementation of the regional transport in logistics and maritime interregional transport are priority issues for improving these connectivity networks (Vineles, 2017). Integrated inter-modal transportation will be an inclusive transport in the logistics service systems to promote trade efficiency and sustainable transport development in the Asia-Pacific region (UNESCAP, 2023). In driving regional economic growth and aggregate demand in trade, infrastructure connectivity is a cornerstone of economic integrations to shape the potential interlinks of production networks and regional markets. With experience in East Asia, relevant infrastructure connectivity and trade are intricately intertwined (UNESCAP, 2014).

Developing economies in Asia have handled 56% (equivalent to 1, 305 million dwt[1]) of world port container traffic geographically (36% in Europe), and their highest liner shipping connectivity contributes to the regional economy (UNCTAD, 2024). Half of the world's seaborne trade passes through the ASEAN region, while nearly 80% of global trade by volume is carried by seaports and 60% of seaborne trade is loaded by developing countries. Almost 20 out of the 30 best-connected ports are located in the Asian region. The eight best-connected ports are ranked from Eastern to Southeast Asia, while the two best ports are in Europe, and the one best port is in Africa (World Bank, 2024). With emerging trade and economic growth in ASEAN, strengthening physical connectivity is an interactive effort to integrate economic connections and regional development. Infrastructure connectivity and its mechanism are important drivers for economic growth and shaping trade patterns with economic interactions across the Southeast Asia and Asia-Pacific regions. Based on the ASEAN master connectivity, the regional economy is comprehensively connected and seamlessly integrated by the logistics industry, both seaborne and dry-port development, to enhance trade more efficiently. However, the economic development related to the linked logistics system among ASEAN countries is heterogeneous and different in each country's type of trade-led growth and specific endowments. Figure 1 shows that liner shipping connectivity has different performances and reflects different levels of trade openness in ASEAN countries. Based on the connectivity index provided by UNCTAD, the highest mean rate over the 5 indexes is found in Singapore and Malaysia (ASEAN, 2023), where their maritime potentialities are geographically pursued to international market hubs in prioritized trade routes and transactional shipments. On the other hand, lower mean rates than the 5 indexes are found in developing and landlocked countries like Lao PDR, Cambodia, and Myanmar. Especially for Lao PDR, the liner shipping networks of connectivity are at the early stage of development. Infrastructure connectivity endowments in the

Figure 1: Trends of connectivity index and trade share in GDP across ASEAN (2006-2019), the summary is based on the UNCTAD data sources in 2024.



logistics industry and relativity are mainly aligned with the path-dependent process of economic performance and trade operations in special economic zones at large, even participating in trade compliance as a member of the World Trade Organization (WTO) in 2011. The path-development progress in liner shipping networks of infrastructure connectivity and multi-modal transport seemingly plays an initial role in the Lao PDR's logistics industry to integrate regional trade and economic activities. The national policy which masters infrastructure connectivity is solely interpreted as that of land-linked economy throughout the logistics industry under the ASEAN connectivity.

The endowments of regional logistics industry is relatively sufficient with the complex maritime trade and international market networks, in Singapore (one of the best hubs in the world, the 1st ranked with 4.3 LPI[2)] score in 2023) and Malaysia, even other ASEAN countries are quite low-ranked in logistics performance. Meanwhile, the logistics industry has a huge gap in infrastructure connectivity and trade efficiency in ASEAN countries, which depends on different human capital and persistent trade compliance. The logistics policy has not been effective in adequately enhancing connectivity to serve regional flows, workforce mobility, investments, and border-trade facilitations, especially supply chain capacity and efficiency integrating dry-ports to seaborne-based trade from landlocked economies across the region and sub-region.

3. Literature review

3.1. Trade and Economic Growth

The previous literature widely suggests the crucial role of trade effects in economic growth. Lucas (1988) theoretically verifies that the level of trade efficiency could shift the upward production frontier and stresses that removing the inefficiency of trade barriers is important to help centrally planned economies to grow fast like market economies. The crucial path-dependent process of knowledge accumulation partially infers trade efficiency through the mechanical ability of human capital in the economic growth stimulus. The possibility that international trade influences economic growth in technological change depends on the economic level and returns to scale. Rivera-Batiz et al. (1991) clarify that the gains from trade among countries are based on comparative advantage of factor endowments and of increasing returns international-trade. While trade restrictions and distortions still have ambiguous impacts on the magnitude and directions of economic growth, high level of trade could induce large volumes of different resources and factor movements across borders and sectors and bring higher growth effects. Endogenous growth theories state that income and substitution effects may lead to the demand curve sloping up and down in association with trade influences and price changes which depends on the imposed demand elasticities. The inefficiency of trade has been alleviated by the reduction in tariff barriers and bottlenecks, thus increased trade could raise the social welfare of the whole economy. International activities by economic openness are substantially increased and enhanced with these high levels of trade performance driven by import and export proportions (Krugman, 1994).

However, endogenous growth theories (Chang et al., 2009; Fatima et al., 2020; Oikawa, 2023), do not consider economic interactions and connections (trade and flow factors cross-borders) among countries in the current integrating sphere of openness (Weil, 2016). While countries with lower incomes are assumed to have faster growth in their certain economic progress and technological change, their trade-growth nexus may differ by country due to the heterogeneous and specific fundamentals of factor endowments (Mahmud and Ishnazorov, 2017). On the other hand, sporadic impediments in the trade costs and the time to trade due to the low logistics performance and inefficient processes result in a lack of multi-modal transport links through supply chain connectivity (Márquez-Ramos et al., 2011). Technological progress in the process of economic integrations are complex trajectories imposed on trade openness. Although they argue that multifaceted connectivity (intermodal integration) and human capital (ergonomic factors) may play a key role in economic connections, these aspects have been less attention in the previous empirical studies.

As the mechanics of economic development, trade effects are enhanced by the degree of stock accumulation of human capital through technological change. Grossman and Helpman (1991; 1994) and Guarini (2011) confirm that when global markets are linked economically, the trade influence arises among countries with exchanges of factors of production (accumulated stock in physical and human capital). Those various trade forms and economic interactions are intertwined to conform to operating openness (Weil, 2016). Countries with trade openness could diversify production factors and movements with flows of technology and knowledge spillovers. Consequently, the degree of integration reflects the influence of economic growth.

While trade enhances more productive capacity, leads to economic growth and countries' welfare, empirical evidence indicates that trade itself has remained deficient in spurring the economy. Several impediments such as inefficiency and insufficiency across boundaries may exist in the mechanism associated with the path-dependent process of human capital (Krugman et al., 2012). The effectiveness boosted by human resource development and spillover effects could prepare conditions for trade-led growth. Interacting economies across borders could array driving forces and core endowments in the trade-growth stimulus and accelerate dynamic conditions in trade openness in developing countries. The aforementioned human capital would be the core element asserted in economic growth theory (Lucas, 1988 and Romer, 1989) and investment in human capital would be a crucial determinant of economic growth and convergence in allocating sufficient resources (Bayraktar-Sağlam and Yetkiner, 2014). Moreover, the function of human resources is partially relevant to accelerate and stimulate the trade-growth nexus. The most influential production factors linked to trade patterns and economic integrations are implicitly related to the path-dependent process of knowledge accumulation in human capital toward economic integration and connectivity. In order to solve issues of trade distortions and disruptions, ergonomic elements by calibrating human capital and technological skills should be considered as factor endowments pieced together in the trade-economic growth nexus.

3.2. Infrastructure Connectivity and Economic Growth

Previous studies treat the infrastructure in the traditional aspect of economic growth as public capital (Foster and Gorgulu, 2022). As capital expenditure, infrastructure capital plays an effective role in productivity and accessibility across developing countries. Increased productivity by implementing infrastructure is reaffirmed as an essential element in the production process to encourage countries with their public investment to initially boost economic growth (Jesús et al., 2000). Improvements in core infrastructure might increase production capacity throughout capital stock, boosting productivity in the short-run and long-term economic growth. Using the data across 40 countries from 1992 to 2010, Agbelie (2014) confirms that transport infrastructure expenditure could lead to higher productivity and allow countries to utilize their potential for comparative advantages through reductions of trade distortions, transportation cost, and time to trade, and benefits to access markets and raw materials. Based on the structural equation model with panel data from 1986 to 2011, Jiang et al. (2017) stress that multi-modal infrastructure investment has comprehensive impacts on economic development, and an adequate investment in infrastructure which reflects the transportation supply as regional adjacent in China has spatial spillover effects and social benefits. As strong evidence across 31 provinces in China (1998–

2007), Hong and Wang (2011) confirm that multi-dimensions of transport infrastructure have essential links to affect regional economic growth and contribute to economic development more efficiently in the regions with poor infrastructure and low productivity in China.

Empirically, the previous studies have pursued the relationship between transport infrastructure and economic growth to shape development policies (Holmgren and Merkel, 2017; Maparu and Mazumder, 2017; Saidi et al., 2018; Kalan and Gokasar, 2020). Infrastructures are the most important and crucial factors for driving economic growth by improving supply chains of trade facilitations and clusters at the national and regional levels (Yu et al., 2012; Wang et al., 2020; Alotaibi et al., 2022). The logistics industry development accompanies the significant contributions of these factors to economic growth and trade performance. Infrastructure investment is a fundamental part of economic policy at the national and regional levels that links infrastructure with trade to affect economic growth in the long run. Traditionally, contributions of transport infrastructure systems are wildly spread by facilitating strong regional connectivity, and increasing trade openness through transport nodes' efforts. Efficient supply chains could accelerate economic development and attract foreign direct investment. The linkages of infrastructure with economic growth are critical factors in discussing the policy implications of sustainable development. Other aspects of infrastructure that affect economic growth are transportation costs, time to trade, market accessibility, and externalities. Saidi et al. (2018) investigate the long-run relationship between transport infrastructure and economic growth in MENA countries. Their study finds that transport infrastructure positively contributes to economic growth across regions with a boost from transport energy consumption. As feedback effects of bidirectional relationships, empirical results lead to a new dimension for investing in modern infrastructure, which pursues energy efficiency and alternative technologies that minimize negative impacts. From an eminent perspective from the meta-analysis between infrastructure and economic growth, Holmgren and Merkel (2017) reveal that the production elasticity of infrastructure differs by type of investment and industry. Investment in infrastructure is a vital part of economic policy at the regional and national levels to accelerate economic growth. Additionally, Calatayud and Palacin (2017) imply that the degree of connectivity metrics in the American region is influenced by the implementation of infrastructure and multi-modal transport. Connectivity in economic activities could provide more comprehensive guidance for the policy improvement of connectivity in countries that face international markets and networking of movements. As the Asia-Pacific connectivity (Shepherd et al., 2011), improving the performance of the multi-modal transport connectivity could bring more gains from trade openness where countries are highly integrated into world markets and strongly connected in logistics services performance toward the regional economy.

Previous studies on infrastructure connectivity investigate the dynamic effects on economic growth. Using dynamic model for 87 countries' data from 1992 to 2017 (Timilsina et al., 2024), the increase in physical infrastructure has larger long-run effects on the GDP in developing economies, while less effects in industrialized countries. Based on GMM analysis in developing countries (Sapkota, 2014), the empirical evidence shows that accessing to traditional aspects of infrastructure such as electricity, drinking water, and transport road density contribute to income and social welfare. This finding could support validity of access to infrastructure services (transport and energy) to pursue sustainable development goals. In China, Li and Qi (2016) test causality between transport connectivity and regional development from 2002-2014. The result confirms the positive impacts of transport logistics connectivity on economic growth. While transport connectivity strengthens the backbone of functional infrastructure and the logistics-based economy, internet users are a crucial key for information connectivity to play a role in economic growth stimulus. Investment in information connectivity is a key element in economic growth with different impacts among regions in China. In Pakistan, Mohmand et al. (2016) examine the impact of transportation infrastructure on economic growth, applying the Granger causality model with panel data (1982-2010). In the short run, there is no causality between transportation and economic growth at the national level, but unidirectional causality from economic growth to infrastructure investment exists in the long run. Bidirectional causality among provinces and unidirectional effects exist in underdeveloped provinces, and an additional analysis further considers the causes of human capital and resource endowments. In the Kingdom of Saudi Arabia, Alotaibi et al. (2022) examine the impact of transport investment and railway accessibility on regional economic growth with a panel model from 1999 to 2018. The findings indicate that transport infrastructure investments could reduce travel costs and time to trade due to improved accessibility and connectivity. Furthermore, they reveal that transport investment and railway accessibility have a positive impact on regional economic growth. Thus, the investment in transport infrastructure is confirmed as an effective factor in boosting economic growth. Using data from 46 developing economies, Saidi et al. (2020) indicate that causality effects between transport infrastructure and economic growth are statistically significant with different levels. Influences from transport logistics infrastructure could contribute to FDI attractiveness and sustainable economic development. Meanwhile, Maparu and Mazumder (2017) also reveal empirical evidence of the direct causality in the long run driving from the transport infrastructure to economic development and urbanization across regions in India (1990-2011).

Regarding ICT connectivity, Arvin et al. (2021) assess the importance of interlinked ICT connectivity penetration, trade openness, and foreign direct investment on economic growth in G-20 countries (1961-2019). ICT connectivity penetration, trade openness, and FDI have significant impacts on long-run economic growth. Economic growth, FDI, and trade openness affect mobile phone connectivity and penetration to internet connectivity in the long run. Similarly, Datta and Agarwal (2004) investigate the dynamic effects of telecommunication infrastructure on economic growth in OECD countries during 1980-1992. The findings show a strong positive relationship between telecommunication infrastructure and economic growth. Higher level of openness supports higher growth substantially. Telecommunication has more impact in countries with small infrastructure endowments but less significant impact in countries with more developed infrastructure industries. Theoretically, Van Zon and Mupela (2016) have confirmed the positive relationship between connectivity and economic growth with the reduction in the costs of transportation and communication.

Infrastructure connectivity is currently relevant to the path dependence of economic interactions and regional integrations in the trade-growth stimulus. Infrastructure connectivity arrays a wide range from traditional transport infrastructure to inter-modal integration in maritime linked the logistics industry geographically (Shepherd et al., 2011). Infrastructure connectivity in the logistics industry may also play a key role in externalities of trade performance to accelerate economic growth. Critically, previous studies aligned with a single aspect of traditional infrastructure have not included integral mechanics in economic development. These empirical studies are solely engaged in trade diversification by infrastructure investment in transport and logistics, which are associated with spatial effects and causality in developing countries (Saidi et al., 2018; 2020; Alotaibi et. al., 2022). However, human capital in trade relativity could play a mechanical role in economic growth. Among ASEAN countries, the logistics industry under infrastructure connectivity endowments and level of human capital remain critical challenges within trade patterns, logistics operations, and economic development. Hence, discussion on benefits from infrastructure connectivity should be more attention to inter-modal transports and logistics endowments. These benefits could stimulate trade-growth performance in the openness sphere (Netirith and Ji, 2022). As technological progress, incorporated infrastructure connectivity and calibrated human capital may lead to high production frontier to leverage trade capacities of nations, thereby influencing economic growth.

4. Methodology: Model, Estimation Technique and Data

This section discusses model specifications for the analysis and data sources.

4.1. Model Specification

This study investigates the impact of infrastructure connectivity and human capital in the trade-growth nexus in ASEAN countries. The traditional production function model treats extending trade and infrastructure connectivity are incorporated as fundamental factors of technological progress that influence the economic growth. Following the endogenous growth theory proposed by Mankiw et al. (1992), the augmenting human capital in the Solow Growth model at time t is specified as follows:

$$Y_t = A_t K_t^{\alpha} H_t^{\gamma} (L_t)^{1-\alpha-\gamma} \quad (1)$$

Where Y_t represents output at time t, K_t is the physical capital at time t, H_t is human capital, while A_t is level of technology, and L_t is labor force at time t. The parameters α and γ denote elasticity of physical and human capital respectively, assuming K_t, H_t, and L_t to be constant returns to scale.

Based on the framework of Grossman and Helpman (1991; 1994), model (1) is extended to incorporate the effects of trade (TRD_t) and infrastructure connectivity (INF_t) on the initial pattern of technology level (technology progress). The initial condition in exogenous technological trajectory crucially plays augmented factors of productivity (based on total factor productivity-TFP) represented as:

$$A_t = A_0 e^{gt}. TRD_t^{\lambda_1}. INF_t^{\lambda_2} \quad (2)$$

Whereas A_0 represents initial level of technology and $e^{gt}. TRD_t^{\lambda_1}. INF_t^{\lambda_2}$ are growth factors of TFP which consist of trade and infrastructure connectivity, according to the assumption of a cutting-edge approach to knowledge accumulation. Based on Mankiw et al. (1992), the A_0 may reflect the general purpose of technology imposed in trajectories (Richard et al., 2005) and the difference of cutting-edge technology (Weil, 2016) influenced by fundamentals such as resource endowments, geography, demography, and institutions, i.e., that lead to differences across countries.

For empirical investigation, the next step consists of transforming the production function into a log-linear form and expressing it in per-capita terms (divided by labor force). In replacing A_t, K_t, and H_t by their respective values above, let's define per-capita terms as follows:

- $y_t = \frac{Y_t}{L_t}$ (Output per capita)
- $k_t = \frac{K_t}{L_t}$ (Physical capital per capita)
- $h_t = \frac{H_t}{L_t}$ (Human capital per capita)

From Eq. (1), then the production function in terms of per-capital form is as:

$$y_t = A_t k_t^{\alpha} h_t^{\gamma} \quad (3)$$

Taking the natural logarithm transformation of both sides of Eq. (3) lead to Eq. (4):

$$\ln(y_t) = \ln(A_t) + \alpha \ln(k_t) + \gamma(h_t) \quad (4)$$

Similarly, Eq. (2) is transformed to the natural logarithm form of technology progress as Eq. (5):

$$\ln(A_t) = \ln(A_0) + (gt + \lambda_1 \ln TRD_t + \lambda_2 \ln INF_t) \quad (5)$$

Insert Eq. (5) in to Eq. (4) to get Eq. (6) as follows:

$$\ln(y_{it}) = \alpha \ln(k_{it}) + \gamma(h_{it}) + \ln(A_0) + (gt + \lambda_1 \ln TRD_{it} + \lambda_2 \ln INF_{it}) + \varepsilon_{it} \quad (6)$$

Output elasticity of technology may reflect the combined effects of the initial pattern of technology level (A_0). Technology growth rate (g) may have the influence of (TRD_{it}) trade and infrastructure connectivity ($INF_{i,t}$). $\varepsilon_{i,t}$ is the idiosyncratic error term in the model.

Based on endogenous growth theory (Romer, 1990; MRW, 1992), the Eq. (6) involves $\ln(A_0)$, the initial level of technology which is inherently difficult to measure especially in developing countries. Also, the term g (labor augmenting), which represents the exogenous growth rate of technology, is a theoretical concept that is not easy to measure. Because of these practical challenges of measurement and data availability for both critical variables, the initial level of technology and exogenous growth rate is absorbed into the fixed effects term (μ_i), which shows the country-specific effect for unobservable time-invariant (heterogeneity) and includes relevant control variables. For empirical purpose, control variables are added into Eq. (6). Thus, Eq. (6) is rewritten concisely as:

$$\ln(y_{it}) = \beta_0 + \alpha \ln(k_{it}) + \gamma(h_{it}) + \lambda_1 \ln(INF_{it}) + \lambda_2 \ln(TRD_{it}) + \delta \ln(X_{i,t}) + \mu_i + \varepsilon_{it} \quad (7)$$

Where δ is output elasticity of the control variable (X_{it}) for country i at time t, the control variables consist of foreign direct investment (FDI), logistics infrastructure endowments, time to trade, and institutional factors across ASEAN countries. μ_i represents the fixed effects, capturing unobserved factors and time-invariant characteristics specified to each country that affect economic growth (dependent variable).

Therefore, the fixed effects model is applied in equation (7) to examine relationships among key variables. In other words, the growth path assumption may lead to find the productivity growth rate driven by sufficient incorporation of potential factors (domain factor shares). In another words, the endogenous growth model is driven by the mechanism employed in the level of technology (the initial pattern of technological progress), which leads to higher economic growth in the long-run economy. Considering the unobserved heterogeneity in the trade-growth performance in ASEAN, the model specification of this study follows analytical techniques of the previous studies (Chang et al., 2009; Santos and Barrios, 2011; Mahmud and Ishnazorov, 2017; Fatima et al., 2020; Oikawa, 2023).

4.2. Data

The data is taken from a variety of sources in ASEAN countries from 2006 to 2019. The dependent variable, GDP per capita (PPP constant-2021 USD), is a proxy of output (y_{it}). (k_{it}) represents capital stock per labour force (L_{it}) (age from 15 to 64).

As augmented Solow Growth, human capital (h_{it}) is generally measured by average years of schooling based on the Barro and Lee (Barro and Lee, 2013; Lee and Lee, 2016). In general, human capital involves educational attainment, experience, and skill training to comprehend a productive sector and social benefits over time (Romer, 1989; 2012). Knowledge capital is more linked to research and development intensively, in which human capital is allocated to define its mechanism in the technology progress in the endogenous growth model. Therefore, the study solely applies the composition of human capital calibrated by the human development index (UNDP) and skill technology frontier index (UNCTAD). This extended human capital may match the study's analysis for consorting trade openness and regional economic integration.

TRD_{it} is percentage share of trade to GDP. Trade is measured by the sum of exports and imports of goods and services as a proxy of trade openness. While there is no exclusively measured trade in principle, even some distortions in data, the trade share in GDP, in which the ratio of trade (exports plus imports) to GDP is relevant to effective changes in growth investigations. Thus, the study follows previous studies (Chang et al., 2009; Fatima et al., 2020). Importantly, the productivity growth where trade activity keeps the primary role in the technology form allows countries to stimulate their progressive economy. Whenever comparative advantage and specialization existed in the openness, more goods and services are productively produced and sold in domestic markets and to other countries with beneficial returns from economic interactions and connections.

INF_{it} is infrastructure connectivity in the form of liner shipping connectivity index (LSCI) applied by the United Nations Conference on Trade and Development (UNCTAD) in maritime transport based on six components, (number of ships, container-carrying capacity, max-vessel size, number of services, number of pairs with direct connection, and companies deploying shipments in ports). LSCI is used as a proxy of infrastructure connectivity. As the MPAC 2025 synergizes, connectivity relies on infrastructure and logistics industry captured by multi-modal transportation, logistic systems, freight traffic, and density of road/rail length (Datta et al., 2004; Hong et al., 2011; OECD, 2016; 2017; Saidi et al., 2018; 2020; Chen et al., 2019; Arvin et al., 2021; Alotaibi et al., 2022). Meanwhile, LSCI represents how countries are well connected to global shipping networks and integration into global supply chains. The accessibility to world markets is related to the effectiveness of multi-modal transport connectivity. Where shipping, cargo, freight networks for traded goods, and regulatory environments are in place, the quality and accessibility of port infrastructure are linked to logistics performance like the backbone (inter-modal) of international trade and the driving engine of the national economy and regional trade-growth performance.

The control variables: FDI_{it} is stock of foreign direct investment, percentage share to GDP. As huge capital flows from international trade, FDI is empirically confirmed as a potential source of technology transfer to influence economic growth and a long-term source of financial development in developing countries. FDI has attracted more emerging countries with the enlargement of manufacturing sectors to stimulate trade and economic growth. Hence, the manufacturing FDI strongly drives forward and backward linkages in industrial processes to higher return to capital, human capital, knowledge transfers in technology, and positive externalities. Based on endogenous growth (Emako et al., 2022; Atobatele, 2023), FDI reflects the crucial part of investment, macro stability, and economic openness in developing countries. The studies provide partially synergized connectivity from logistics infrastructure endowments (international sea cargo, international sea container, and rail length). Their measurements rely on the ASEAN-based data in million tons throughput of TEUs and in kilometres, respectively. Additionally, relevant indicators of prevailing connectivity are the time to trade (export and import), which represents that the shorter time to trade perhaps means a higher degree of connectedness in economic interactions across the border economy (UNCTAD). The time to export is measured by the leading time in number of days associated with exporting a cargo of goods in sea transport within 4 predefined stages (document preparation, customs clearance-inspections, inland transport-handling, and port-terminal handling). The time estimation for each stage starts from the initial moment and runs until the process is completed, while the export processing zone allows the authorized firms to apply the fast-track procedures under the economic operation programs. It is assumed that both exporters and importers are committed in completing and the processes have not wasted time, leading to no delays. Each stage has required a 1-day minimum.

Measures of performing infrastructure and transport can not capture the inter-modal and multi-modal connectivity as input factors in the trade-growth nexus. Therefore, this study aims to consider different series of the data for infrastructure connectivity from the perspective of liner shipping connectivity based on the UNCTAD and the MPAC 2025, which extends the incorporated functions in infrastructure connectivity networks and logistics endowments. Essentially, trade-led growth is mechanized by the augmented human capital calibrating skill technology frontier, embracing the operations in the logistics industry.

The annual data of variables are collected from the World Bank (WDI) and the Penn World Tables (PWT), the UNDP and the UNCTAD. The sample period is from 2006 to 2019 for ASEAN countries. Table 1 shows data descriptions and their sources.

Table 1: Sources and indicators of key variables (2006-2019)

Variable name	Acronym	Descriptions	Sources
Output	y_{it}	Gross Domestic Product Per Capita (USD in PPP Constant-2021)	WDI
Capital Stock	k_{it}	Capital stock per labor at PPPs (Millions USD, 2017)	PWT
Human Capital	h_{it}	Composition of skill technology frontier index	UNDP and UNCTAD
Trade	TRD_{it}	Trade (%) in GDP, the sum of exports and imports of goods and services shared in GDP (trade ratio)	UNCTAD
Connectivity	INF_{it}	Liner shipping connectivity index based on concepts of UNCTAD, the base period or value is 100 (2006).	UNCTAD
Foreign Direct Investment	FDI_{it}	Foreign Direct Investment, stock inflows (%) in GDP	UNCTAD
Logistics endowments	$SEAC_{it}$ $SECON_{it}$ $RAIL_{it}$	International Sea Cargo throughput (TEUs), International Sea Container throughput (TEUs) and Total Rail Length (Kilometres)	ASEAN
Institutions	GOV_{it} REG_{it}	Government Effectiveness and Regulatory in Percentage Tile Ranges	UNCTAD
Time to Trade	TE_{it} TI_{it}	Time to Export and Time to Import (numbers of days in trading process)	UNCTAD

Note: PPP = Purchasing Power Parity; UNDP = United Nations Development Programme; UNCTAD = United Nations Conference on Trade and Development.

4.3. Descriptive Statistics

Table 2 indicates the descriptive analysis. The total sample size is N = 140 (number of countries n = 10 and time period T = 14). There are some missing data in infrastructure connectivity (INF_{it}), logistics endowments, and time to trade (export and import). Especially, the Lao PDR has a lack of data on connectivity because infrastructure connectivity is at the early stage of development based on the first special economic zone (SEZ) established in 2003 for supporting the trade networks in East-West Economic and North-South Economic Corridors in the Greater Mekong Subregion (GMS). While the logistics industry in Lao PDR was established, the Lao PDR-China railway was officially launched in 2021 to connect the liner shipment across borders with ASEAN countries. Additionally, the rail length data is also not available for Brunei Darussalam. Thus, the available data of connectivity for analysis is 126 samples. GDP (y_{it}) and capital (k_{it}) are in per capita terms in the economic growth theory based on Mankiw et al. (1992). Calibrated human capital (h_{it}) is a composited index that consists of the human development index and skill technology frontier one, while trade (TRD_{it}), infrastructure connectivity (INF_{it}), FDI (FDI_{it}), logistics endowments (SEC_{it}, $SCON_{it}$, $RAIL_{it}$), institutions (GOV_{it}, REG_{it}), and time to trade (TE_{it}, TI_{it}) are transformed into the natural logarithm. Although the mean and standard devia-

Table 2: Descriptive Statistics

Variables	Observation	Mean	Standard Deviation	Minimum	Maximum
Ln GDP pc (y_{it})	N = 140	9.5075	1.1381	7.8160	11.6754
Ln Capital (k_{it})	N = 140	4.2441	1.3623	1.4489	6.7741
Human capital (h_{it})	N = 140	0.3057	0.2154	0.0461	0.8505
Ln Trade (TRD_{it})	N = 140	11.3334	1.7322	7.5715	13.5839
Ln Connectivity (INF_{it})	N = 126	6.1920	1.1993	4.1013	7.7767
Ln FDI (FDI_{it})	N = 139	10.6585	1.7530	6.7665	14.3678
Ln Inter-Sea Cargo (SEC_{it})	N = 123	11.1609	2.2246	6.7393	13.9743
Ln Sea Container ($SCON_{it}$)	N = 121	7.7238	1.9363	4.4485	10.5239
Ln Rail ($RAIL_{it}$)	N = 122	6.6913	2.1186	1.3863	8.7358
Ln Government (GOV_{it})	N = 140	3.7238	0.8693	0.6491	4.6052
Ln Regulatory (REG_{it})	N = 140	3.6152	1.0105	−0.7227	4.6052
Ln Time to Export (TE_{it})	N = 127	3.6638	1.1048	1.7918	5.7301
Ln Time to Import (TI_{it})	N = 127	3.7031	1.1891	1.3863	5.6348

Source: Authors' computed summary.

tion indicate that human capital development is not different among ASEAN countries, the mean and standard deviation reveal that the ASEAN economies may have differences in trade, FDI, and inter-sea endowments of connectivity.

5. Empirical Results and Discussion

5.1. Empirical Results

Table 3 shows the estimated results of equation 9 with fixed effect estimation.[3] Column (1) indicates that the coefficients of capital and human capital are positive and statistically significant at 1% and 5% levels. The 1% increase in capital and human capital affects per capita GDP growth by 0.45% and 1.40%, respectively. As the results of columns (2)-(5) show, the coefficient of trade is positive performance and statistically significant at the 1% level. These significant results confirm Grossman and Helpmen (1994). However, all coefficients of FDI are insignificant. When the logistics endowments are taken into account in column (3), infrastructure connectivity is found to affect GDP growth. International sea cargo and sea containers are positive and statistically significant at 1% level and 5% level, respectively. On the other hand, total rail length is not found to contribute to economic growth. Importantly, the regression in column (4) includes the institutional factors. The regulation has been found to be positive and statistically significant at the 10% level, except government effectiveness. In column (5), time to trade (export and import) is included. The time to export is seemingly negative and statistically significant at the 10 % level, while the time to import turns positive and statistically significant at the 5% level. The results in column (5) imply that infrastructure connectivity and human capital are fundamental

Table 3: Panel data model in fixed effects, ASEAN sample 2006-2019

Variables	Acronym	(1)	(2)	(3)	(4)	(5)
$\ln k_{it}$	Capital	0.4549*** (0.0657)	0.0712** (0.0313)	0.049** (0.0243)	0.0263 (0.0513)	0.424 (0.0859)
h_{it}	Human Capital	1.3989** (0.6451)	1.0938* (0.5649)	0.0792 (0.0911)	1.0419* (0.5398)	1.1830* (0.5219)
$\ln TRD_{it}$	Trade		0.1558*** (0.0274)	0.0876*** (0.0150)	0.1483*** (0.0291)	0.1779*** (0.0296)
$\ln INF_{it}$	Connectivity		0.1160*** (0.0297)	0.0587* (0.0278)	0.0917** (0.0341)	0.0936*** (0.0264)
$\ln FDI_{it}$	FDI		0.0355 (0.0495)	−0.0217 (0.0244)	0.0585 (0.0269)	0.0776 (0.0723)
$\ln SEC_{it}$	Sea Cargo			0.1189*** (0.0197)		
$\ln SCON_{it}$	Sea Container			0.0308** (0.0126)		
$\ln RAIL_{it}$	Rail Length			0.0232 (0.0388)		
$\ln GOV_{it}$	Government E.				−0.0383 (0.0277)	
$\ln REG_{it}$	Regulation				0.0505* (0.0269)	
$\ln TE_{it}$	Time to Export					−0.0479* (0.0211)
$\ln TI_{it}$	Time to Import					0.0729** (0.0199)
Time	Dummy		yes	yes	yes	yes
_cons		7.1492***	−19.6933	−34.706***	−19.6027	4.8053
No. observation		140	126	108	126	113
No. group id		10	9	8	9	9
within R^2		0.7870	0.9099	0.9842	0.9137	0.9078
Pro>F		0.0000	0.0000	0.0000	0.0000	0.0000

Standard-error in parentheses *p< .10, **p< .05, ***p< .01.
Note: *, **, and *** imply statistical significance on the 10%, 5%, and 1% level, respectively.

driving forces of the trade-growth nexus. As significant magnitudes, the 1% increase in infrastructure connectivity and human capital bounds GDP per capita by about 0.09% and 1.18% respectively. The fractions may boost the trade-growth nexus, with approximately 0.18% increase of GDP per capita influenced by trade performance in column (5).

This study further explores the combined impact of human capital and connectivity. In Table 4, human capital and trade are mostly significant and positive in all estimations, while the magnitude of coefficients has diminished when additional variables are included. The magnitude of human capital has decreased from 6.20 in column (6) to 1.10 in column (9), and the coefficient of trade has decreased from 0.25 to 0.13. Even though human capital keeps playing a crucial role in economic growth, the coefficients of interaction term of human capital with trade and connectivity are both solely negative and statistically significant at 10% and 5% levels, respectively. Interestingly, the connectivity interacting with the time to export is revealed as highly positive and statistically significant at the 1% level in accelerating the trade-led growth in column (8), there is also a positive clue for the interaction with time to import in the perspectives of combined effects in column (9).

Table 4: Fixed effect with interaction, ASEAN sample 2006-2019

Variables	Acronym	(6)	(7)	(8)	(9)
lnk_{it}	Capital	0.0087 (0.0484)	0.0273 (0.0365)	0.1013 (0.0610)	0.1434** (0.0461)
h_{it}	Human Capital	6.205** (2.6797)	4.8277** (1.6561)	1.1034** (0.3593)	1.0788*** (0.2918)
$lnTRD_{it}$	Trade	0.2462*** (0.0613)	0.1172** (0.0385)	0.1028*** (0.0089)	0.1291*** (0.0219)
$lnINF_{it}$	Connectivity	0.0629 (0.0438)	0.2074** (0.0691)	−0.0191 (0.0564)	0.0257 (0.0332)
$lnFDI_{it}$	FDI	0.0501 (0.0445)	0.0608 (0.0524)	0.1237** (0.0452)	0.0893* (0.0467)
$lnTRD_{it}$ x h_{it}	Trade x Human Capital	−0.4351* (0.1960)			
$lnINF_{it}$ x h_{it}	Connectivity x Human Capital		−0.605** (0.2109)		
$lnTE_{it}$	Time to Export			−0.161*** (0.0301)	
$lnINF_{it}$ x $lnTE_{it}$	Connectivity x Time to Export			0.0326*** (0.0059)	
$lnTI_{it}$	Time to Import				−0.127*** (0.014)
$lnINF_{it}$ x $lnTI_{it}$	Connectivity x Time to Import				0.025*** (0.002)
Time	Dummy	yes	yes	yes	yes
_cons		−30.84**	−28.123*	11.4475	12.3538
No. of observation		126	126	113	113
No. of Group ID		9	9	9	9
Within R^2		0.9300	0.9306	0.9137	0.9276
Prob>F		0.0000	0.0000	0.0000	0.0000

Standard-error in parentheses *p<.10, **p<.05, ***p<.01.
Note: *, **, and *** imply statistical significance on the 10%, 5%, and 1% level, respectively.

Additionally, the study intends to mitigate the potential endogeneity and reverse causality issues by applying instrumental variable in the 2SLS based on Felbermayr (2005) and Baum et al. (2007). The lagged GDP per capita and connectivity are selected as instruments for trade. The lagged GDP per capita and infrastructure connectivity are positive and statistically significant at the 1% level (endogenous factors in the trade-growth nexus) as in the Appendix B. The first stage reveals that trade is robust for heteroscedasticity and autocorrelation with a *p-value* of 0.0000 of F-statistics (11.51). The test of under-identification rejects the null hypothesis of Kleibergen-Paap rk LM statistic: Chi^2 11.914 by the *p-value* of 0.0026, indicating that the model is under-identified. However, the selected instruments have weak indentification based on the higher Kleibergen-Paap rk Wald F-statistic: 11.506 than the 10% and 20% of Stock-Yogo weak ID test critical values, while Hansen J statistic (overidentification test of all instruments) and Endogeneity test of endogenous regressors are confirmed as the trade instruments (lagged GDP per capita and connectivity). Subsequently, those instruments could correspond to an initial level of trade and have contemporaneous effects to enhance economic growth across ASEAN countries

(Fatima et al., 2020).

5.2. Discussion

The empirical results in Table 3 show that infrastructure connectivity and human capital affect economic growth. This table infers the empirical test for augmented Solow growth in ASEAN economies; the importance of physical and human capital seems to be confirmed. While the capital is highly significant in columns (1-3), using alternative control variables loses its significance in specifications in columns (4) and (5). Human capital as a proxy of human development is a crucial factor for the effective performance of connectivity via skilled technology in the ASEAN region.

The coefficients of trade are positively significant and play a leading role in economic growth. Increasing international trade activity seems to be a fundamental driver of growth to leverage regional economic openness and integrate international markets. The positively significant coefficient of infrastructure connectivity implies intra-trade enhancement via linking logistics endowments for regional economic development. Moreover, logistics endowments partially strengthened by infrastructure connectivity are crucial factors for the trade-economic growth stimulus. Maritime endowments (except the rail) are more integrated and connected in ASEAN economies. Consequently, the relationship between connectivity and economic growth may be context-dependent and affected by supporting factors from human capital, trade, and regulation. With trade influencing, institutions, logistics endowments, and time to trade could also play important roles in determining economic growth in ASEAN countries.

On the other hand, the findings in Table 4 show a different picture. In column (6), while the coefficient of trade (TRD_{it}) is still positive and significant, the coefficient of the interaction term between trade and human capital ($TRD_{it}xh_{it}$) is negatively significant of the combined effect. This result is not aligned with the hypothesis. The negative sign of interaction among connectivity and human capital ($INF_{it}xh_{it}$) in column (7) implies that human capital does not work well to enhance connectivity performance. Although these results are robust, the human capital index could be reconsidered. Importantly, the clue findings of connectivity that interacted with time to trade are positively and vitally moderated in trade processes and procedures, efficiently accelerating the trade-growth performance in ASEAN economies.

These findings are consistent with the previous studies (Munim and Schramm, 2018; Katrakylidis and Madas, 2019). Inefficient infrastructure connectivity has existed in the Asia-Pacific region. As Márquez-Ramos et al. (2011) indicate, some components of connectivity with maritime trade and non-containerized trade have negative imputs on economic growth (Del Rosal and Moura, 2022; Netirith and Ji, 2022). Those critical impacts may be implicitly related to trade costs and high freight rates in time to trade (export-import) encompassing multifaceted connectivity and logistics endowments. While to synergize economic integrations and connections in ASEAN, the effectiveness of infrastructure connectivity should be improved to reduce bottleneck impediments in the trade-growth nexus. ASEAN productivity and economy of scales are based on linking inter-modal connectivity to prioritized trade routes and supply chain efficiency in the logistics industry performance. These linking efforts are crucial to connect those maritime economies where trade enhances economic growth by developing infrastructure connectivity through effective logistics mechanisms.

It must be pointed out that this study has room for further improvement. Firstly, another index of human capital should be reconsidered as related skills in trade compliance and connectivity performance. Table 1 shows that the data used is the composition of the human development index and the skill technology frontier index. Since this variable is a key independent variable, another candidate of the human capital index is needed to elaborate the estimation. Secondly, the specified model cannot fully mitigate the potential endogeneity issues between the explained variable (economic growth) and the explanatory variables (trade, human capital, and FDI). One possible solution is to find out the instrument variable. This study attempted to find a good instrument, but it was unsuccessful. The other solution is to use the GMM model. Although several types of GMM estimations were applied, the results were not better than the fixed effect estimations because of some missing data existed among key variables and insufficient time sevies for the GMM estimation.

6. Conclusion and Policy Implications

This study investigates the impact of infrastructure connectivity and human capital in the trade-growth nexus across ASEAN countries, using panel data from 2006–2019 with fixed effect models. The results imply that the infrastructure of liner shipping connectivity influences intra-trade, which links logistics endowments to bolster regional economic development. Human capital is mostly embodied in the skilled technology frontier for trade openness. Economic interactions and integrations led by active international trade in ASEAN should leverage logistics endowments aligned with infrastructure connectivity and human capital engaging skills.

As the empirical results show, each component connectivity in the logistics industry, incorporating technological changes, is a main determinant for regional economic integration. Under this situation, efficient supply chain networks are efficiently triggered as an engine to yield trade expansion through economic openness. On the other hand, the leading time to export in the trade process, such as time delays and less frequent connectivity, could impede economic growth. As discussed before, theoretically, human capital is an important factor in enhancing economic growth. Previous studies also find that human development in the technological frontier is a clue to the mechanized trade-growth performance. However, the variation of human capital among the ASEAN region brings unexpected results in estimations. Despite the empirical results, the inter-modal infrastructure connectivity in the logistics industry may improve prioritized trade routes for connection and integration of ASEAN economies. The effectiveness of logistics connectivity and human capital embodied technological skills could serve as core functions to some degree, shaping trade efficiency and economic growth under the integration of the ASEAN region into international markets. To promote international trade, connectivity could help to accelerate regional economic growth in different income levels across the ASEAN region. Hence, embodied human capital in technology could play an important role in the leveraged transitional technology and soft-skills policy across the logistics industry to provide an effective supply chain for trade performance.

The logistics industry of infrastructure connectivity is vitally required in developing economies, islands, and landlocked countries like the Lao PDR. Infrastructure connectivity should be treated as a public good towards the technological progress of economic development in ASEAN economies. The contemporary policy of landlocked countries is to remove trade distortions and reduce bottleneck impediments, the leading time to trade entirely cross-border through regional economic connections. The productivity in ASEAN economies is based on effectiveness in prioritized trade routes and efficient supply chains, which are linked to inter-modal connectivity in the logistics industry and accessibility to trade openness in maritime economies. Therefore, the ASEAN master connectivity could be enhanced to promote regional linkages in trade efficiency with inclusive growth and development. Thus, the logistics endowments should be synergized with inter-modal infrastructure connectivity in the framework of MPAC 2025. Crucial components of regional multimodal connectivity should be improved in the trade-led growth as follows: 1). The implementation of adequate infrastructure and connectivity endowments in trade and economic corridors; 2). Investment in prioritized trade routes for efficient connected supply chains acrossborders to boost regional economic integration and connections; 3). Removal of inefficient scales (trade cost, time delivery, and frequency) and providing enough shipment capacity in the logistics industry for competitive trade.

Acknowledgements

The authors appreciate and acknowledge the School Office, the Graduate School of Economics, Ritsumeikan University, and the Government of Japan (JDS and JICE) for supporting research and funds. We would express heartfelt thanks to committees, professors, research colleagues, and audiences for their great advice, insightful recommendations, informative suggestions and comments around research seminars; the International Conference on the Economic Policy and Theory, Meiji University, Tokyo, Japan (11-13 September 2024); the 17th International Conference on the Regional Innovation and Cooperation in Asia (RICA), Jinan University, Guangzhou, China (9-10 November 2024); the 3rd National Conference on Academic Research "Empowering Community: *Education, Economic Resilience, and Renewable Energy for Sustainable Environment*", Champasack University, Champasack Province, Lao PDR (27-28 November 2024); and the 9th International Conference on Economic Structures (ICES 2025), Chiba University of Commerce, Chiba, Japan (8-9 March 2025).

Notes

1) Based on the UN Trade and Development (UNCTADstat 2024), dwt = dead weight ton, unit of the fleet in ship carrying capacity.
2) Based on the World Bank 2018, LPI = the Logistics Performance Index (LPI) is one of the seven trusts in logistics capability and cargo performance (other: customs, infrastructure, intershipments, logistics competence, tracking and tracing, and timeliness).
3) Based on the Hausman test, the test result reveals that the null hypothesis is rejected with a highly significant *p-value* of 0.0001 (Prob > Chi^2). Therefore, the panel model in fixed effect is properly confirmed as the appropriate model properties (N > T). Hence, the fixed effect model could solve country heterogeneity.

References

ADB. (2023). https://www.gihub.org/infrastructure-monitor/and http://dx.doi.org/10.22617/FLS168388-2

Agbelie, B. R. D. K. (2014). An Empirical Analysis of Three Econometric Frameworks for Evaluating Economic Impacts of Transportation Infrastructure Expenditures across Countries. *Transport Policy, 35,* 304-310. https://doi.org/10.1016/j.tranpol.2014.06.009

Alotaibi, S., Quddus, M., Morton, C., & Imprialou, M. (2022). Transport Investment, Railway Accessibility, and Their Dynamic Impacts on Regional Economic Growth. *Research in Transportation Business & Management, 43,* 100702. https://doi.org/10.1016/j.rtbm.2021.100702

Arvin, M. B., Pradhan, R. P., & Nair, M. (2021). Uncovering Interlinks among ICT Connectivity and Penetration, Trade Openness, Foreign Direct Investment, and Economic Growth: The Case of the G-20 Countries. *Telematics and Informatics, 60,* 101567. https://doi.org/10.1016/j.tele.2021.101567

ASEAN Secretariat. (2016). *Master Plan on ASEAN Connectivity 2025.* ASEAN Secretariat. https://asean.org/our-communities/asean-connectivity/

ASEAN. (2023). *https://investasean.asean.org/logistics*

ASEAN. (2024). *https://asean.org/our-communities/economic-community/*

Atobatele, O. O. (2023). Determinants of Foreign Direct Investment Flows to Africa: A Dynamic Panel Data Analysis. *Modern Economy, 14*(06), 847-866. https://doi.org/10.4236/me.2023.146046

Baum, C. F., Schaffer, M. E., & Stillman, S. (2007). Enhanced Routines for Instrumental Variables/Generalized Method of Moments Estimation and Testing. In *The Stata Journal, 7*(4).

Barro, R. J., & Lee, J. W. (2013). A New Data Set of Educational Attainment in the World, 1950-2010.

Journal of Development Economics, 104, 184–198. https://doi.org/10.1016/j.jdeveco.2012.10.001

Bayraktar-Sağlam, B., & Yetkiner, H. (2014). A Romerian Contribution to the Empirics of Economic Growth. *Journal of Policy Modeling, 36*(2), 257–272. https://doi.org/10.1016/j.jpolmod.2014.01.001

Brooks, D. H. (2016). Connectivity in East Asia. *Asian Economic Policy Review, 11*(2), 176–194. Blackwell Publishing. https://doi.org/10.1111/aepr.12132

Calatayud, A., Mangan, J., & Palacin, R. (2017). Connectivity to International Markets: A Multi-Layered Network Approach. *Journal of Transport Geography, 61,* 61–71. https://doi.org/10.1016/j.jtrangeo.2017.04.006

Chen, Y., Fan, Z., Zhang, J., & Mo, M. (2019). Does the Connectivity of the Belt and Road Initiative Contribute to the Economic Growth of the Belt and Road Countries? *Emerging Markets Finance and Trade, 55*(14), 3227–3240. https://doi.org/10.1080/1540496x.2019.1643315

Chang, R., Kaltani, L., & Loayza, N. v. (2009). Openness Can Be Good for Growth: The Role of Policy Complementarities. *Journal of Development Economics, 90*(1), 33–49. https://doi.org/10.1016/j.jdeveco.2008.06.011

Datta, A., & Agarwal, S. (2004). Telecommunications and Economic Growth: A Panel Data Approach. *Applied Economics, 36*(15), 1649–1654. https://doi.org/10.1080/0003684042000218552

Del Rosal, I., & Moura, T. G. Z. (2022). The Effect of Shipping Connectivity on Seaborne Containerised Export Flows. *Transport Policy, 118,* 143–151. https://doi.org/10.1016/j.tranpol.2022.01.020

Emako, E., Nuru, S., & Menza, M. (2022). The Effect of Foreign Direct Investment on Economic Growth in Developing Countries. *Transnational Corporations Review, 14*(4), 382–401. https://doi.org/10.1080/19186444.2022.2146967

Fatima, S., Chen, B., Ramzan, M., & Abbas, Q. (2020). The Nexus Between Trade Openness and GDP Growth: Analyzing the Role of Human Capital Accumulation. *SAGE Open, 10*(4). https://doi.org/10.1177/2158244020967377

Felbermayr, G. J. (2005). Dynamic Panel Data Evidence on the Trade-Income Relation. *Review of World Economics, 141*(4), 583–611. https://doi.org/10.1007/s10290-005-0046-4

Foster, V., Rana, A., & Gorgulu, N. (2022). *Understanding Public Spending Trends for Infrastructure in Developing Countries.* http://www.worldbank.org/prwp.

Fugazza, M., & Hoffmann, J. (2017). Liner Shipping Connectivity as Determinant of Trade. *Journal of Shipping and Trade, 2*(1). https://doi.org/10.1186/s41072-017-0019-5

Grossman, G. M., & Helpman, E. (1991). Trade, Knowledge Spillovers, and Growth. *European Economic Review, 35*(2–3), 517–526. https://doi.org/10.1016/0014-2921(91)90153-a

Grossman, G. M., & Helpman, E. (1994). Endogenous Innovation in the Theory of Growth. *Journal of Economic Perspectives, 8*(1), 23–44. https://doi.org/10.1257/jep.8.1.23

Guarini, G. (2011). *Innovation and Growth in the Grossman-Helpman's Model with Increasing Returns: A Note.*

Hong, J., Chu, Z., & Wang, Q. (2011). Transport Infrastructure and Regional Economic Growth: Evidence from China. *Transportation, 38*(5), 737–752. https://doi.org/10.1007/s11116-011-9349-6

Holmgren, J., & Merkel, A. (2017). Much Ado about Nothing? – A Meta-Analysis of the Relationship between Infrastructure and Economic Growth. *Research in Transportation Economics, 63,* 13–26. https://doi.org/10.1016/j.retrec.2017.05.001

Jiang, X., He, X., Zhang, L., Qin, H., & Shao, F. (2017). Multimodal Transportation Infrastructure Investment and Regional Economic Development: A Structural Equation Modeling Empirical Analysis in China from 1986 to 2011. *Transport Policy, 54,* 43–52. https://doi.org/10.1016/j.tranpol.2016.11.004

Jesús, M., Rodríguez, D., Delgado, M. J., & Alvarez, I. (2000). *Public Productive Infrastructure and Economic Growth.* https://www.researchgate.net/publication/23730050

Jouili, T. A. (2019). Determinants of Liner Shipping Connectivity. *International Journal of Advanced and Applied Sciences, 6*(11), 5–10. https://doi.org/10.21833/ijaas.2019.11.002

Kalan, O., & Gokasar, I. (2020). A Dynamic Panel Data Approach for the Analysis of the Growth Impact of Highway Infrastructures on Economic Development. *Modern Economy, 11*(03), 726–739. https://doi.org/10.4236/me.2020.113053

Katrakylidis, I., & Madas, M. (2019). International Trade and Logistics: An Empirical Panel Investigation of the Dynamic Linkages between the Logistics and Trade and Their Contribution to Economic Growth*. *International Journal of Economics and Business Administration: VII*(4). www.icabe.gr

Krugman, P. R. (1994). *Rethinking International Trade.* MIT Press.

Krugman, P. R., Obstfeld, Maurice., & Melitz, Marc J. (2012). *International Economics Theory and Policy 9th Ed.*

Lee, J.-W., & Lee, H. (2016). Human Capital in the Long Run. *Journal of Development Economics, 122,* 147–169. https://doi.org/10.1016/j.jdeveco.2016.05.006

Li, K. X. & Qi, G. (2016), "Transport Connectivity and Regional Development in China", *Journal of International Logistics and Trade, 14*(2), 142–155. https://doi.org/10.24006/jilt.2016.14.2.142

Lucas, R. E. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics, 22*(1), 3–42. https://doi.org/10.1016/0304-3932(88)90168-7

Lun, Y. H. V., & Hoffmann, J. (2016). Connectivity and Trade Relativity: the Case of ASEAN. *Journal of Shipping and Trade, 1*(1). https://doi.org/10.1186/s41072-016-0015-1

Mahmud, S. F., & Ishnazorov, D. (2017). Trade-Growth Nexus and Industrial Policy. *Industrial Policy and Sustainable Growth* (pp. 1–19). Springer Singapore. https://doi.org/10.1007/978-981-10-3964-5_4-1

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics, 107*(2), 407–437. https://doi.org/10.2307/2118477

Maparu, T. S., & Mazumder, T. N. (2017). Transport Infrastructure, Economic Development, and Urbanization in India (1990–2011): Is There any Causal Relationship? *Transportation Research Part A: Policy and Practice, 100,* 319–336. https://doi.org/10.1016/j.tra.2017.04.033

Márquez-Ramos, L., Martínez-Zarzoso, I., Pérez-García, E., & Wilmsmeier, G. (2011). "Special Issue on Latin-American Research" Maritime Networks, Services Structure and Maritime Trade. *Networks and Spatial Economics, 11*(3), 555–576. https://doi.org/10.1007/s11067-010-9128-5

Mohmand, Y. T., Wang, A., & Saeed, A. (2016). The Impact of Transportation Infrastructure on Economic Growth: Empirical Evidence from Pakistan. *Transportation Letters, 9*(2), 63–69. https://doi.org/10.1080/19427867.2016.1165463

MPAC 2025. (2023). *Mid-Term Review Executive Summary of the Master Plan on ASEAN Connectivity 2025.*

Munim, Z. H., & Schramm, H.-J. (2018). The Impacts of Port Infrastructure and Logistics Performance on Economic Growth: the Mediating Role of Seaborne Trade. *Journal of Shipping and Trade, 3*(1). https://doi.org/10.1186/s41072-018-0027-0

Netirith, N., & Ji, M. (2022). Analysis of the Efficiency of Transport Infrastructure Connectivity and Trade. *Sustainability (Switzerland), 14*(15). https://doi.org/10.3390/su14159613

OECD. (2017, July 11). *Infrastructure Connectivity in Lao PDR.* OECD iLibrary. Retrieved October 22, 2022, from https://www.oecd-ilibrary.org/finance-and-investment/oecd-investment-policy-reviews-lao-pdr/infrastructure-connectivity-in-lao-pdr_9789264276055-12-en.

Oikawa, K. (2023). Economic Growth: Why Are There Rich and Poor Countries?. In: Urata, S., Akao, KI., Washizu, A. (eds) Sustainable Development Disciplines for Society. Sustainable Development Goals Series. Springer, Singapore. https://doi.org/10.1007/978-981-19-5145-9_9

Reza, M. (2015). Liner Shipping Connectivity and International Trade in Maritime Southeast Asian Countries. *Journal of International Logistics and Trade, 13*(3).

Richard G. Lipsey., Kenneth I. Carlaw., & Clifford T. Bekar. (2005). *Economic Transformations: General Purpose Technologies and Long-Term Economic Growth.* Oxford University Press.

Rivera-Batiz, L., & Romer, P. (1991). *International Trade with Endogenous Technological Change.* https://doi.org/10.3386/w3594

Romer, P. (1989). *Endogenous Technological Change.* https://doi.org/10.3386/w3210

Saidi, S., Shahbaz, M., & Akhtar, P. (2018). The Long-Run Relationships between Transport Energy Consumption, Transport Infrastructure, and Economic Growth in MENA Countries. *Transportation Research Part A: Policy and Practice, 111,* 78-95. https://doi.org/10.1016/j.tra.2018.03.013

Saidi, S., Mani, V., Mefteh, H., Shahbaz, M., & Akhtar, P. (2020). Dynamic Linkages between Transport, Logistics, Foreign Direct Investment, and Economic Growth: Empirical Evidence from Developing Countries. *Transportation Research Part A: Policy and Practice, 141,* 277-293. https://doi.org/10.1016/j.tra.2020.09.020

Santos, Lorelied. A., & Barrios, E. B. (2011). Small Sample Estimation in Dynamic Panel Data Models: A Simulation Study. *Open Journal of Statistics, 01*(02), 58-73. https://doi.org/10.4236/ojs.2011.12007

Sapkota, J. B. (2014). *Access to Infrastructure and Human Development: Cross-Country Evidence.*

Shepherd, B., Serafica, R. B., Bayhaqi, A., & Jing, H. (2011). The Trade Impact of Enhanced Multimodal Connectivity in the Asia-Pacific Region. *Source: Journal of Economic Integration, 26*(4), 624-650.

Timilsina, G., Stern, D. I., & Das, D. K. (2024). Physical Infrastructure and Economic Growth. *Applied Economics, 56*(18), 2142-2157. https://doi.org/10.1080/00036846.2023.2184461

UNCTAD. (2024). *https://unctadstat.unctad.org/insights/theme/26#indicator-18*

UNESCAP. (2014). *Regional Connectivity for Shared Prosperity.*

UNESCAP. (2023). *Strengthening Regional Cooperation for Seamless and Sustainable Connectivity.* Asia-Pacific Countries with Special Needs Development Report 2023. The 79th Commission Session.

Van Zon, A., & Mupela, E. (2016). Connectivity and Economic Growth. *Macroeconomic Dynamics, 20*(8), 2148-2172. https://doi.org/10.1017/s136510051500022x

Vineles, P. (2017). *ASEAN Connectivity: Challenge for an Integrated ASEAN Community.* www.rsis.edu.sg

Wang, C., Lim, M. K., Zhang, X., Zhao, L., & Lee, P. T.-W. (2020). Railway and Road Infrastructure in the Belt and Road Initiative Countries: Estimating the Impact of Transport Infrastructure on Economic Growth. *Transportation Research Part A: Policy and Practice, 134,* 288-307. https://doi.org/10.1016/j.tra.2020.02.009

Weil, D. (2016). *Economic Growth International Edition* (3rd ed., pp. 258-347). Routledge.

World Bank. (2024). https://databank.worldbank.org/metadataglossary/world-development-indicators/series/IS.SHP.GCNW.XQ

Yu, H. (2017). Infrastructure Connectivity and Regional Economic Integration in East Asia: Progress and Challenges. *Journal of Infrastructure, Policy and Development, 1*(1), 44-63. https://doi.

org/10.24294/jipd.v1i1.21

Yu, N., De Jong, M., Storm, S., & Mi, J.（2012）. Transport Infrastructure, Spatial Clusters, and Regional Economic Growth in China. *Transport Reviews, 32*(1), 3–28. https://doi.org/10.1080/01441647.2011.603104

Appendix A:

Autocorrelation test

Breusch-Pagan LM test of independence: $chi^2(36)=255.262$, Pr = 0.0000

Based on 13 complete observations over panel units

Heteroskedasticity test

Modified Wald test for groupwise heteroskedasticity in fixed effect regression model

H0: $sigma^2(i) = sigma^2$ for all i

$chi^2(9) = 713.98$ Prob > $chi^2 = 0.0000$

Appendix B:

Summary results for first-stage regressions

Variable name	Acronym	Shea Partial R^2	Partial R^2	F(2, 102)	P-value
Ln Trade	$Ln\ TRD_{it}$	0.2603	0.2603	11.51	0.0000

NB: first-stage F-stat heteroskedasticity and autocorrelation-robust

Underidentification tests

Ho: matrix of reduced form coefficients has rank = K1-1 (underidentified)

Ha: matrix has rank = K1 (identified)

	Chi^2	P-value
Kleibergen-Paap rk LM statistic	11.29	0.0035
Kleibergen-Paap rk Wald statistic	24.13	0.0000
Underidentification test (Kleibergen-Paap rk LM statistic)	11.914	0.0026

Weak identification test

Weak identification test (Kleibergen-Paap rk Wald F statistic):		11.506
Stock-Yogo weak ID test critical values:	10% maximal LIML size	8.68
	15% maximal LIML size	5.33
	20% maximal LIML size	4.42
	25% maximal LIML size	3.92
NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors		

	Chi^2	P-value
Hansen J statistic (overidentification test of all instruments):	7.929	0.0049
Endogeneity test of endogenous regressors:	12.477	0.0004