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Bridging Continents: Comparative Analysis of Infrastructure, Digitalization, and Institutional Drivers of Logistics Performance in Asian and European Economies

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Abstract:
Strengthening logistics performance has emerged as a key priority in global development agendas. This study is a comparative study of top 20 economies of Asia and Europe from 2007 to 2024, where dependent variable is Logistics performance Index (LPI), exploratory variables are Government Digital Index (GDI) and Internet Users (IT), and Controlled variables are Infrastructure Quality (INF), Logistics Services, Clearance process (ECP), Exports of goods and services, with the moderating effect of INF and GDI. The study has applied robust approach for study, Hausman test, VIF, Cross sectional dependency test and RE model is preferred over FE. The findings are INF has negative impact on LPI, the moderating effect of GDI and INF is not significant in both the regions, IT shows insignificant relationship with LPI, this states that adoption of IT doesn't improve LPI without creating friendly environment with digital infrastructure. Policy Suggestions are, both regions need to improve technological advancement in Logistics sector, digitalisation can help to create multimodal environment friendly transportation system.

Keywords: Logistics Performance Index; Digitalisation; Transport Infrastructure; Infrastructure Development.

1. Introduction

Logistics has influenced certain activities ever since the early years of commercial relationships. In the last few decades, digital technology has transformed various industries such as manufacturing and trading enterprises (Spivakovskyy et al., 2023). Digitalisation is shaping the way of doing business, the shipping industry, and logistics. Logistics plays a crucial role in an economy. The usage of digital information in logistics management can increase competitiveness on global scales in areas such as information, planning, transportation, inventory control, and handling (Kuteyi and Winkler, 2022). Digitalisation of logistics is now known as Industry 4.0. The meaning of supply chain digitization is the linking of information, networking, and digitalisation to enable smart management and a synchronized system throughout the supply chain process (Sun et al., 2022). Digitalisation refers to the use of digital technologies to enhance the provision, coordination, and management of freight transport and logistics services (Wang and Sarkis, 2021). The sustainability and digitalisation are among the main trends reshaping logistics in the dynamic world of today (Köhlera and Brauer, 2023). Digitalization has reshaped supply chains by improving efficiency, promoting economic integration, and increasing responsiveness to market demands.

Countries around the world have invested heavily in resources that enhance logistics infrastructure capabilities and have made notable progress. Strengthening logistics and supply chain performance has emerged as a key priority in global development agendas (Iskandar and Arifin, 2023), aimed at achieving economic benefits and streamlined supply chains. Logistics costs directly impact economic activities, and further enhancements in logistics efficiency can lower prices for consumers and increase profit margins for companies (Estrada et al., 2019). The effectiveness of logistics reflects one of the key drivers of economic development across countries and regions (Philipp, 2020). Information technology is, and will continue to be, an essential enabler for efficient supply chain management (Ross, 2016).

Asia is emerging as the hub of the logistics industry; a report by McKinsey highlighted that Asia will account for nearly half of world trade growth by 2030. Asian trade growth with the rest of the world will account for nearly 55 percent, while intra-Asia trade will cover the balance. Logistics performance is the accumulation of efforts from logistics entities operating in an economy and is measured by LPI (Logistics Performance Index) scores (Senir, 2021). The LPI evaluates six critical components of logistics systems: customs performance, infrastructure quality, international shipment arrangements, logistics competence, tracking and tracing capabilities, and delivery timeliness.

The emergence of new digital technologies and the constantly growing application of information and communication technologies (ICT) across all sectors of the economy have been major policy priorities of the European Union (EU) over a long period. However, there are very few studies that have tested the impact of digitalisation on the Logistics Performance Index (LPI). Therefore, the findings of this study could provide new insights and identify influential factors affecting the LPI.

2. Theoretical analysis and research hypotheses

2.1 Logistics and Digitalisation

The logistics and freight industry has witnessed a period of transformation. Digitalisation is one of the key elements of competitive success in transport companies, as it has a direct impact on the supply chain, service quality, and supply chain speed (Smirnov et al., 2022). The digitalisation of logistics processes depends on a high level of technological readiness and innovation capabilities (Moldabekova et al., 2021). Digitalisation can provide a competitive advantage to an enterprise by automating manual tasks and optimizing logistics operations (Spivakovskyy et al., 2023). IT-enabled systems for information sharing have become essential in the modern logistics era as they support socioeconomic benefits; they help attract FDI and enhance export performance (Anwar et al., 2022). New technology in the logistics sector can significantly enhance logistics, boost customer satisfaction, and increase profitability (Köhlera and Brauer, 2023). Through digital platforms, enterprises can obtain and analyze various supply chain data in real time, including orders, inventory, and logistics information. Information and technology-enabled firms can respond quickly to changes through effective internal operations and collaboration with suppliers and customers (Daya et al., 2019). (Moldabekova et al., 2021), in a study of EU countries, found that digitalisation affects logistics performance, with the integration of digital technologies and internet services predetermining logistics effectiveness and service efficiency. Digitalisation enables digitised documentation, automated check-ins, traffic management, and enhanced port operations (Chen et al., 2023).

Digital tools such as AI, blockchain, IoT, and big data analytics have significantly improved logistics performance, promoted economic integration, optimized resource allocation, and supported environmental sustainability. Logistics 4.0 integrates performance measurement systems with machines and logistics networks, enabling real-time monitoring and improved decision-making (Götz et al., 2023). The role of IoT in real-time tracking of goods and environmental conditions, revolutionising supply chain management. Ports are now using digital technologies to enhance cooperation with stakeholders and automate terminal equipment operations (Bhaskar and Chen, 2023). The digitalisation process supports long-term planning and knowledge acquisition.

(Kuteyi and Winkler, 2022), in their study of Sub-Saharan Africa, highlighted the importance of digitalisation in logistics and trade. (Moldabekova et al., 2021) also emphasized that country-level innovation and technological readiness are significant drivers of logistics.

Some authors have highlighted the challenges of logistics digitalisation. (Iskandar and Arifin,2023), in their study of Indonesia, found that a decline in the LPI is linked to multiple problems, particularly the need for Customs and Excise to optimize the national supply chain. (Köhlera and Brauer, 2023) noted that most digital technologies are currently focused on sustainability rather than economic advantage. Stress the need to systemise digital features and integrate multiple processes to improve logistics. (Kine et al., 2022), in the context of low-income countries (LICs), highlighted low

traceability, lack of real-time mechanisms, and high dependence on manual labour. (Barykin et al., 2023) pointed out that digitalisation also affects employees, working conditions, management skills, and competencies, requiring a multifaceted assessment of technological impacts. Finally, (Labhard & Lehtimäki, 2022) emphasised that the adoption of digital technologies represents one of the most significant transformations in global economic activity.

H_1: The digitalisation can enhance the ranking of the logistics performance of an economy.

H_2: Infrastructure and digitalisation have a positive moderating effect on logistics performance.

3. Research Methodology

3.1 Data source & Time Frame

Table 1 shows the variables, its functions and data sources. The dependent variable for this study is Logistics performance Index (LPI), exploratory variables are Gov. Digital Index (GDI) and Internet Users (per 100) (IT), and Controlled variables are Quality of trade- and transport-related infrastructure (INF), Logistics Services Quality (CQL), Efficiency of the clearance process (ECP), Exports of goods and services (% of GDP) (EGS). The data sources are etrade for GDI and IT and other variables are taken from WDI. The time frame for this study is from 2007 to 2024 (based on the availability of the data). Researchers have selected top 20 economies of Asia and Europe to make it comparative study; due to some non-availability we have to drop some countries form the Asian region.

Table 1: Data, functions and Sources

Sl. No	Variable Type	Variable Function	Variable Definition	Source
1.	Dependent	LPI	Logistics performance Index	WDI
2.	Exploratory	GDI	Gov. Digital Index	eTrade
3.		IT	Internet Users (per 100)	eTrade
4.	Controlled	INF	Quality of trade- and transport-related infrastructure	WDI
5.		CQL	Logistics Services Quality	WDI
6.		ECP	Efficiency of the clearance process	WDI
7.		EGS	Exports of goods and services (% of GDP)	WDI

Source: Authors own compilation.

3.2 Model construction and specification

This paper develops the following model to test the hypotheses of the paper. The paper uses a random effects model and controls for yearly effects.

$$LPI_{it} = \beta_0+\beta_1 INF_{it} + \beta_2 ECP_{it} + \beta_3 CQL_{it} + \beta_4 IT_{it} + \beta_5 EGS_{it} + u_{it} \quad \text{Eq 1}$$

$$LPI_{it} = \gamma_0 + \gamma_1 INF_{it} + \gamma_2 GDI_{it}+\gamma_3 ECP_{it}+\gamma_4 CQLit+\gamma_5 ITit + \gamma_6 EGSit+u_{it} \quad \text{Eq 2}$$

$$LPI_{it}=\delta_0+\delta_1 INF_{it}+\delta_2 GDI_{it} + \delta_3(INF_{it}\times GDI_{it}) + \delta_4 ECP_{it}+\delta_5 CQL_{it} + \delta_6 IT_{it} +\delta_7 EGS_{it}+u_{it} \quad \text{Eq 3.}$$

The equations modelling in this section shows the relationship between the variables. Equation 1 shows INF as the main exploratory variable, along with controlled variables ECP, CQL and IT and EGS. Second equation extends the variables by adding GDI, to show how digitalisation can affect the LPI. The third equation shows the moderating interaction (INF* GDI) to test how GDI strengthens the INF. The model in equation 3 are estimated by using the panel regression techniques, which can help to identify both individual and time variant patterns across countries. i represents country and t represent time.

The study uses panel data for analysis and applies a series of panel regression models to control, unobserved heterogeneity and time-invariant country effects. The study has applied, RE model. Along

with a series of diagnostic tests such a unit root tests, Hausman test, Breusch-Pagan, and VIF to ensure robustness of the model selection.

4. Empirical analysis

4.1 Descriptive statistical analysis

Table 2 displayed the data of statistical analysis, shows the results of all variables, the highest LPI of Asia is 4.3 whereas minimum is 1.86 which reflects a significant disparity among the countries. In Europe the maximum of LPI is 4.23 and minimum is 2.37 which also shows high

Table 2:

Descriptive statistical analysis

Table 2.1 Asian Region

	LPI	GDI	ECP	INF	CQL	IT	EGS
Mean	3.122	0.566	2.865	57.421	3.079	46.213	45.698
Median	3.145	0.565	2.826	49.5	3.082	46.335	31.437
Maximum	4.3	0.913	4.2	148	4.4	97.69	212.779
Minimum	1.86	0.176	1.8	1	2	0.22	8.581
Std. Dev.	0.487	0.18	0.52	36.438	0.527	28.314	39.681

Source: Authors own compilation.

Table 2.2 European Region

	LPI	GDI	ECP	INF	CQL	IT	EGS
Mean	3.657	0.766	3.451	25.392	3.664	77.488	52.263
Median	3.76	0.785	3.578	19	3.757	81.72	43.692
Maximum	4.23	0.971	4.207	99	4.315	99	135.058
Minimum	2.37	0.513	1.939	1	2.457	24.66	21.728
Std. Dev.	0.413	0.103	0.506	21.868	0.457	15.892	23.19

Source: Authors own compilation.

disparity, irrespective of regions there is a significant disparity among the countries. The maximum value of GDI in Asian and European countries are 0.913 and 0.971 respectively. The maximum IT value is 97.69 in Aisa and 99 in Europe, while the minimum value is 0.22 in Asia and 24.66 in Europe, which shows the high disparities. Other results are presented in table 2.

Table 3 shows the results of correlation matrix whereas the table 3.1 and 3.2 shows the region-specific data. In table 3.1 LPI is highly positively correlated with ECP and CQL and highly negatively associated with INF the GDI is correlated with IT. In table 3.2 LPI is positively associated with ECP and CQL and highly negatively associated with INF. Which shows that all the variables move in same direction irrespective of region.

Table 3: Correlation Matrix

Table 3.1 Asian Region

	LPI	GDI	ECP	INF	CQL	IT	EGS
LPI	1						
GDI	0.703	1					
ECP	0.953	0.679	1				
INF	-0.928	-0.652	-0.884	1			
CQL	0.977	0.701	0.939	-0.9	1		

IT	0.644	0.911	0.623	-0.575	0.638	1	
EGS	0.466	0.412	0.505	-0.373	0.431	0.382	1

Source: Authors own compilation

.

Table 3.2 European Region

	LPI	**GDI**	**ECP**	**INF**	**CQL**	**IT**	**EGS**
LPI	1						
GDI	0.645	1					
ECP	0.959	0.638	1				
INF	-0.937	-0.605	-0.925	1			
CQL	0.973	0.666	0.934	-0.907	1		
IT	0.631	0.836	0.636	-0.576	0.655	1	
EGS	0.253	0.138	0.251	-0.218	0.263	0.336	1

Source: Authors own compilation.

Table 4: Hausman Test Results for Europe and Asia

Region	**χ^2**	**df**	**p-value**
Europe	9.84	6	0.132
Asia	11.08	6	0.086

Source: Authors own compilation.

Hausman test is used to check the cross-sectional dependency. The results are presented in table 4. Null hypothesis is there is no cross-sectional dependency, whereas the alternative hypothesis is there is cross-sectional dependency present. The results of table 5 shows that p- value is

Table 5: Cross Sectional dependency test of Europe and Asia

Region	**z-statistic**	**p-value**
Europe	1.52	0.128
Asia	5.54	< 0.001

Source: Authors own compilation.

0.128 higher than 0.05, we fail to reject and there is no significant cross-sectional dependency. Whereas in Asia the cross-sectional dependency is present. As there is present of cross-sectional dependency, we have used the robust standard errors to obtain the reliable results.

Table 6 shows the random effects regression results of both European and Asian region; the table includes the impact with or without moderating effect of GDI on INF. The RE model is preferred over the FE model after applying the Hausman test. In both the regions the ECP and CQL shows positive and significant effects on Logistics Performance Index (LPI).

Infrastructure (INF) shows negative and significant relationship with LPI in both the regions, which shows that high infrastructure alone cannot improve the LPI or logistics performance. This also shows that creating only INF is not sufficient both the regions need to effectively utilise, integrate and govern the INF for better LPI. The moderating of GDI on INF in both the regions are not significant and negative. The results implies that high digitalisation make dimmish the role of INF in overall LPI. This could be because in port management most of the work is still done in physical mode and more time is needed to transit from physical form to digital form. EGS shows a weak and positive impact on LPI in both the regions, which shows the export of goods and services have a low impact on LPI. IT shows insignificant relationship with LPI, which also highlight that adoption of IT doesn't improve the LPI without creating a positive environment and digital infrastructure in developed as well as emerging economies.

Table 6: Random Effects Model Results for Europe and Asia (Dependent Variable: LPI)

Region	**Europe**		**Asia**	
Variables	**RE Model**	**RE Moderation**	**RE Model**	**RE Moderation**
GDI	–0.084 (0.103)	0.089 (0.131)	–0.072 (0.098)	–0.021 (0.124)
INF	–0.00296*** (0.00050)	–0.00044 (0.00192)	–0.00293*** (0.00045)	–0.00266*** (0.00059)
INF × GDI	_	–0.00447 (0.00277)	_	–0.00085 (0.00124)
ECP	0.194*** (0.051)	0.224*** (0.040)	0.185*** (0.042)	0.176*** (0.043)
CQL	0.526*** (0.051)	0.497*** (0.040)	0.529*** (0.042)	0.522*** (0.044)
IT	0.00060 (0.00062)	–0.00015 (0.00079)	0.00072 (0.00058)	0.00073 (0.00058)
EGS	0.00043* (0.00021)	0.00005 (0.00029)	0.00041* (0.00020)	0.00038. (0.00021)
Constant	1.112*** (0.142)	1.094*** (0.149)	1.124*** (0.123)	1.147*** (0.128)
R^2	0.975	0.973	0.975	0.975

*Note: Standard errors in (), ***p < .001; **p < .01; p < .05.*
Source: Authors own compilation.

The results of this study indicate that both European and Asian economies rely on quality of logistics, services and customs efficiency rather than on digitalisation. Both the regions need to improve the digitalisation environment for logistics performance.

5. Discussion and Policy Implications

The findings of this study support the "Institutional complementarity framework" which suggests that institutions are more efficient when they are mutely supportive. The findings shows that INF alone cannot improve the logistics performance. We have compared the two regions of the world European which is generally considered as the Developed countries region around the world and Asian region which is generally considered as the emerging part of the world. The penetration of digitalisation is high and infrastructure is more mature in European region but still the GDI along with INF doesn't have much effect on logistics performance. On the other hand, Asian region with relatively low digitalisation and immature infrastructure shows insignificant results, which also shows many countries in the region still need to increase the digital framework. The interconnectivity of the region can play a major role in improving the logistics performance.

From the results we concluded there is a need to emphasize on integrated policy approaches region wise. There is a need to improve the logistics systems by introducing smart logistics system, digital platforms for smooth and timely process, homogeneity on cross border digital frameworks. Overall, both regions can benefit from aligning physical infrastructure development with institutional reforms and digital transformation strategies, ensuring that investments translate into long-term trade facilitation and supply chain resilience.

Some of the past studies have provided some suggestions for the improvement of logistics performance. Study of (Moldabekova et al.,2021) emphasized that industry 4.0 need high level of digital readiness and technological advancement to improve the logistics performance of a country.

(Anwar et al.,2022) highlighted the issue of the low infrastructure such as road, rail warehousing and low transportation facilities is one the major problem in low performing countries of LPI. Improving this infrastructure can improve the LPI score significantly. (Zapara et al.,2024) suggested that digitalisation can help in integrated information in transportation, multimodal transportation, environment friendly logistics.

This study provides strong insights on LPI and digitalisation but we have some limitations, firstly the availability of data is a major issue in Asian countries, if more updated data is provided it will be beneficial for future study. Future research can be done on more regional groups or can take more developed and developing countries. The future researchers can take more past data in account for further research.

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