International Journal of Research in Human Resource Management

E-ISSN: 2663-3361
P-ISSN: 2663-3213
IJRHRM 2024; 6(2): 339-345
www.humanresourcejournal.com
Received: 05-10-2024
Accepted: 06-11-2024

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Assessing the influence of GDP and trade balance on logistics performance index (LPI): A cross-country analysis

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DOI: https://doi.org/10.33545/26633213.2024.v6.i2d.235

Abstract
This study explores the relationship between economic indicators—Gross Domestic Product (GDP) and trade balance (Goods and Services Revenue, GSR)—and logistics performance across countries, focusing on the Logistics Performance Index (LPI). The objectives were to evaluate how GDP influences LPI, assess the impact of GSR on LPI, and analyze the combined effects of GDP and GSR on logistical efficiency. Data on GDP, GSR, and LPI from various nations were collected from credible sources, including the World Bank. Statistical methods such as descriptive analysis, correlation analysis, and multiple regression were employed.
Findings revealed significant correlations between LPI and both GDP and GSR. High-GDP countries generally exhibited superior LPI scores, indicating that greater economic capacity translates to improved logistics performance. Additionally, a positive trade balance (GSR) was associated with higher LPI, emphasizing the critical role of efficient logistics in supporting trade. Regression analysis showed that GDP and GSR together explain 45% of the variance in LPI, highlighting their combined influence on logistical outcomes. Countries with robust logistics infrastructure, such as Singapore and Sweden, achieved higher LPI scores, while those with trade deficits faced logistical inefficiencies.

Keywords: Logistics performance index, GDP, trade balance, global logistics, economic growth, cross-country analysis

Introduction
The rapid growth of e-commerce has dramatically changed the global economy. Transforming business operations and how consumers interact with products and services. As online shopping platforms and digital transactions become more widespread, the e-commerce sector has expanded beyond traditional geographic barriers. which helps businesses. It has never been easier to reach a global audience (Leung, 2018) [30]. These changes have intensified competition and greatly increased market accessibility. This is because businesses around the world are now competing for the attention of a global customer base (Turban *et al*., 2020) [31]. The expansion of e-commerce has contributed to the complexity and interconnectedness of global supply chains. Currently, various companies. It is sourcing products from different parts of the world, leveraging digital platforms to improve operations and manage inventory in real time (Hübner *et al*., 2016) [32]. This international integration leads to efficient logistics. more and lower operating costs. However, managing these global networks also poses new challenges to ensure on-time delivery (Wang, 2019) [33]. Coordinating international suppliers and distribution channels to meet increasing consumer demands for speed and reliability are key challenges. Impact on logistics and supply chains the rise of e-commerce has clearly impacted many key dimensions of global logistics. including warehouse Inventory management Last mile delivery solution technological progress and environmental considerations as the demand for online retail grows, businesses strategically positioned… has adjusted according to the settings Warehouses and distribution centers enable faster fulfillment and delivery to geographically dispersed customers (Richards, 2019) [34]. This has led to the reconfiguration of supply chains to focus on customer proximity and speed, as opposed to bulk shipping to centralized retail locations.
one of the most significant innovations driven by e-commerce growth is the development of last-mile delivery solutions. Last-mile delivery refers to the final stage of the shipping

process, where goods are transported from a distribution hub to the end consumer (Gevaers *et al*., 2014) [35]. This stage is often the most expensive and logistically challenging, with the growing expectation for faster deliveries putting immense pressure on logistics providers to offer efficient and cost-effective last-mile services (Lim *et al*., 2018) [36]. The rise of same-day or next-day delivery options exemplifies how consumer demand has reshaped logistical practices, pushing companies to adopt new technologies and optimize their delivery networks (Wang *et al*., 2021) [37].

Challenges of the e-commerce supply chain

Traditional supply chain strategies were designed to support brick-and-mortar retail operations, where goods were transported in bulk to physical stores for consumer purchase (Rushton & Walker, 2019). In contrast, the e-commerce model necessitates a different approach, with individual packages being delivered directly to consumers' doorsteps, often within short delivery windows (Grant, 2021). This shift has required logistics providers to adapt their networks to handle smaller, more frequent shipments, increasing both delivery volumes and the demand for fast, reliable service (Hübner *et al*., 2016) [32]. The challenges associated with this transformation include increased transportation costs, logistical inefficiencies, and a higher risk of delays or delivery failures, particularly in rural or remote areas (Lim *et al*., 2018) [36].

In addition to logistical complexities, the environmental impact of e-commerce-driven logistics has become a growing concern. The increased frequency of small-package deliveries, coupled with shorter delivery times, has led to a significant rise in carbon emissions and traffic congestion (Wang *et al*., 2021) [37]. As businesses seek to address these challenges, many are turning to sustainable logistics practices, such as green packaging, electric delivery vehicles, and carbon offset programs (Chowdhury *et al*., 2021) [40].

Review of Literature

The digital transformation of logistics has brought significant changes to how businesses operate, particularly within the e-commerce sector. Adeniran *et al*. (2024) [41] explored how digital transformation, a critical component of the Fourth Industrial Revolution, has reshaped operational processes in logistics. The study discusses how digital technologies, such as e-commerce platforms, are integral to the future of commerce, emphasizing the transformative effects on logistics networks and sustainability.

Zhao, Gong, and Shen (2024) [42] focused on cross-border e-commerce logistics, developing an optimization model for logistics distribution network design using genetic algorithms. This research underlines the importance of optimizing logistics for cross-border e-commerce to enhance efficiency, reduce costs, and promote international trade. Their work provides a blueprint for improving logistics network planning and management using advanced algorithmic approaches.

Brown, Johnson, and Wilson (2005) [6] analyzed the role of e-commerce technologies, such as real-time monitoring, predictive analytics, artificial intelligence (AI), and blockchain, in transforming supply chain management. Their research emphasizes how these technologies have improved operational efficiency, customer service, and decision-making within retail supply chains, although challenges remain, particularly regarding system integration and cybersecurity risks.

The significance of logistics and infrastructure in promoting international trade was highlighted by Liu (2024) [44], who demonstrated that efficient logistics systems enhance transportation, warehousing, and inventory management. However, the study also points to challenges such as aging infrastructure and environmental concerns, suggesting future trends in green and smart logistics to ensure sustainability.

Orozonova *et al*. (2024) [45] conducted a regional study on the digital economy's impact on the logistics industry in Henan Province, China. Through regression analysis, they demonstrated a positive correlation between digitalization and the economic performance of the logistics sector. Their findings emphasize the importance of adopting digital technologies to improve logistics operations and contribute to economic growth, particularly in the tertiary sector.

Reverse logistics, an often-overlooked aspect of the supply chain, is another critical component reshaped by e-commerce. Abdullahi, Mohamud, and Mohamud (2024) [46] conducted a comprehensive bibliometric analysis of reverse logistics in e-commerce between 2003 and 2023. The study highlights the growing research focus on this area, particularly the need for inclusivity in global research contributions, as reverse logistics continues to play an important role in modern supply chains.

Van Ha (2023) [47] explored the impact of digital transformation on Vietnam's logistics service industry. The study points out that the rapid growth of e-commerce requires logistics providers to integrate IT and digital tools into their operations to meet evolving market demands. This research underscores the necessity for logistics service providers to adapt their business models to remain competitive in the global market.

Jiang *et al*. (2022) [48] examined how Chinese manufacturing suppliers in the nonwoven fabric industry respond to challenges in global value chains (GVCs) through GVC upgrading facilitated by e-commerce. Their research identified internal and external challenges these suppliers face and how e-commerce enables them to enhance economic, environmental, and social aspects of their operations, contributing to the literature on supplier resilience in global markets.

Kawa (2021) [49] studied the European Union's logistics networks in response to e-commerce growth. The research points to increased demand for fast delivery, compelling logistics companies to invest in new technologies and infrastructure to meet consumer expectations. Kawa also discusses the challenges related to last-mile delivery and how urban logistics strategies are evolving to mitigate these difficulties.

Finally, Gawankar, Rathore, and Kamble (2021) [50] focused on the e-commerce-driven transformation of India's logistics network. They emphasized how the rapid expansion of e-commerce has increased demand for efficient and reliable logistics services. The study highlights the adoption of AI and IoT in logistics and the ongoing challenges of last-mile delivery in a diverse and geographically vast market like India.

Problem Statement

Global logistics efficiency, as measured by the Logistics Performance Index (LPI), is crucial for economic growth

and competitiveness. While GDP often reflects a country's economic capacity, the trade balance, indicated by Goods and Services Revenue (GSR), affects the demand and strain on logistical infrastructure. However, the relationship between GDP, GSR, and LPI remains underexplored, especially concerning how economic scale and trade balances influence logistical performance across countries. This research seeks to bridge this gap by analyzing the impact of GDP and GSR on LPI across diverse economies, offering insights into the key economic factors that enhance or hinder logistical effectiveness.

Objectives

- To analyze the relationship between GDP and LPI across selected countries: Determine whether countries with higher GDP generally exhibit stronger logistical performance as reflected in their LPI scores.
- To examine the impact of GSR (trade balance) on LPI: Identify if trade surplus or deficit correlates with the efficiency of a country's logistics infrastructure.
- To compare the combined effects of GDP and GSR on LPI: Evaluate the extent to which both GDP and GSR jointly influence LPI and assess if their effects are mutually reinforcing or independent.
- To provide strategic recommendations based on findings: Suggest policy interventions or infrastructural improvements that countries could adopt to enhance their LPI scores based on GDP and GSR patterns.

Research Methodology

1. Data Collection

- Collect LPI, GDP, and GSR data for each selected country from credible sources (e.g., World Bank, IMF).
- Use cross-sectional data covering recent years to capture the latest trends and economic conditions.

2. Data Analysis Techniques

- **Descriptive Statistics:** Calculate means, standard deviations, and skewness for LPI, GDP, and GSR for each country to provide an initial overview.
- **Correlation Analysis:** Examine the linear relationships between GDP, GSR, and LPI to identify any significant correlations.
- **Regression Analysis:** Employ multiple regression to quantify the effect of GDP and GSR on LPI, adjusting for other possible influencing factors (e.g., region, population size).
- **Comparative Analysis:** Segment countries by GDP levels and GSR balance (e.g., high-GDP vs. low-GDP and surplus vs. deficit countries) to explore trends and variations.

3. Interpretation and Reporting

- Interpret the results of statistical analyses to understand the influence of GDP and GSR on LPI.
- Summarize findings with visual aids such as graphs and tables for clarity.
- Develop strategic recommendations based on the insights drawn from the data.

4. Limitations and Future Scope

- Acknowledge potential limitations, such as unobserved variables and data constraints.
- Suggest areas for further research, such as incorporating additional economic indicators or longitudinal studies.

Table 1: Descriptive statistics

		LPI	GSR	
India	Mean	3.246666667	-73117183606	2033.761207
	Standard Error	0.04307616	11951901792	97.41472276
	Standard Deviation	0.12922848	35855705375	292.2441683
	Skewness	0.589005913	0.11924238	0.106320843
	Range	0.34	1.26319E+11	894.6711
Singapore	Mean	4.0725	1.30625E+11	70651.94348
	Standard Error	0.039449335	14997943093	4211.745597
	Standard Deviation	0.111579568	42420589060	11912.61549
	Skewness	1.437553571	0.616187269	0.534749391
	Range	0.3	1.08459E+11	31528.7842
Netherlands	Mean	4.0725	-1577734857	53835.91488
	Standard Error	0.027434988	253492123.4	1901.614748
	Standard Deviation	0.077597864	716983997.7	5378.578734
	Skewness	1.036153791	0.59251178	0.231470809
	Range	0.17	1805400000	16497.6261
United states kingdom	Mean	3.97375	-6.70727E+11	67699.14104
	Standard Error	0.041141633	59909372016	2925.060814
	Standard Deviation	0.116366109	1.69449E+11	8273.321348
	Skewness	-2.261673258	-0.581158493	0.757940992
	Range	0.37	4.65309E+11	23488.5729
Sweden	Mean	4.08125	19225491294	54893.1871
	Standard Error	0.026621521	2492164432	1112.984183
	Standard Deviation	0.075297031	7048905480	3147.994654
	Skewness	1.186900436	0.141137187	1.358024073
	Range	0.2	18406785370	9478.2512
Norway	Mean	3.7075	43243191425	83844.75338
	Standard Error	0.004909903	19944106300	4620.040021
	Standard Deviation	0.013887301	56410451238	13067.44651

	Skewness	1.4401646	1.74291978	0.855332672
	Range	0.03	1.69409E+11	40458.4329
Luxemdourg	Mean	3.77375	28059461143	20888.57846
	Standard Error	0.097448475	1011588312	1465.796825
	Standard Deviation	0.275625911	2861203821	4145.8995
	Skewness	1.433938018	0.438927924	0.173464775
	Range	0.62	8388951957	12094.4683
Canada	Mean	3.81375	-21857813508	48156.43866
	Standard Error	0.041573408	6024527732	1745.395968
	Standard Deviation	0.117587354	17039937650	4936.725298
	Skewness	0.78091872	0.65657453	0.451824303
	Range	0.27	39577571982	13195.3316
France	Mean	3.8625	-33372018379	40761.80751
	Standard Error	0.010978876	6925177486	876.0630791
	Standard Deviation	0.03105295	19587359845	2477.880576
	Skewness	0.644061189	-0.997340175	0.167452392
	Range	0.06	58986988735	7398.2842
Australia	Mean	3.75375	44792077756	57318.92189
	Standard Error	0.009988833	13593413201	2014.271465
	Standard Deviation	0.028252686	38447978615	5697.220047
	Skewness	-0.509147601	-0.100652756	0.301509739
	Range	0.09	1.04822E+11	15158.8828

India

Mean LPI is relatively moderate (3.25) with minimal skewness (0.59). GSR shows a large negative mean (-73.1 billion), indicating a trade deficit. The high standard deviation in GSR (35.9 billion) suggests variability in trade values, while skewness close to zero (0.12) implies slight symmetry. The economic metric has a mean of 2033.76 with minimal skewness, indicating a balanced distribution around this mean.

Singapore

Singapore's high LPI mean (4.07) reflects strong logistics performance, but skewness (1.44) indicates a distribution leaning towards lower values. GSR shows a significant positive mean (130.6 billion), indicating a trade surplus. The high standard deviation in GSR (42.4 billion) suggests large fluctuations. The economic metric's mean (70,651.94) with slight skewness (0.53) shows a fairly symmetric distribution.

Netherlands

Similar to Singapore, the Netherlands has a high mean LPI (4.07) with moderate skewness (1.04). GSR shows a slight deficit with a negative mean (-1.58 billion). Lower variability and skewness in GSR indicate a more stable performance compared to other nations. The economic metric mean (53,835.91) and low skewness (0.23) indicate a stable distribution.

United Kingdom

LPI mean (3.97) is slightly lower than that of the Netherlands and Singapore, with negative skewness (-2.26), suggesting higher values are less frequent. The large negative GSR mean (-670.7 billion) highlights a trade deficit. High standard deviation (169.4 billion) reflects significant variability in trade. Economic metric means (67,699.14) with moderate skewness (0.76) shows variability.

Sweden

LPI mean (4.08) is among the highest, with significant skewness (1.19), indicating values skew towards lower LPI. GSR shows a positive mean (19.2 billion), suggesting a trade surplus with moderate standard deviation (7 billion). Economic metric mean (54,893.19) and high skewness (1.36) indicate the data distribution is more concentrated toward lower values.

Norway

Mean LPI (3.71) with high skewness (1.44) indicates values skewed towards lower logistics performance. GSR shows a trade surplus with a mean of 43.2 billion, but high standard deviation (56.4 billion) indicates substantial variability. Economic metric has the highest mean (83,844.75) among the countries, with considerable variability (skewness: 0.86).

Luxembourg

LPI mean (3.77) with high skewness (1.43) suggests values skewed lower. GSR's positive mean (28.06 billion) reflects a trade surplus with a moderate standard deviation (2.86 billion). Economic metric mean (20,888.58) with low skewness (0.17) indicates a relatively stable distribution.

Canada

LPI mean (3.81) and moderate skewness (0.78) show a balanced performance. GSR has a negative mean (-21.9 billion), suggesting a trade deficit, with moderate variability. Economic metric mean (48,156.44) is relatively high, with moderate skewness (0.45).

France

LPI mean (3.86) with moderate skewness (0.64) is slightly higher than Canada's. GSR's negative mean (-33.4 billion) suggests a trade deficit. Economic metric mean (40,761.81)

with low skewness indicates a stable economic performance.

Australia

LPI mean (3.75) with slight negative skewness (-0.51) indicates a balanced distribution around the mean. GSR shows a trade surplus (mean of 44.8 billion), but high variability (standard deviation: 38.4 billion). Economic metric mean (57,318.92) is among the highest, with low skewness indicating stability.

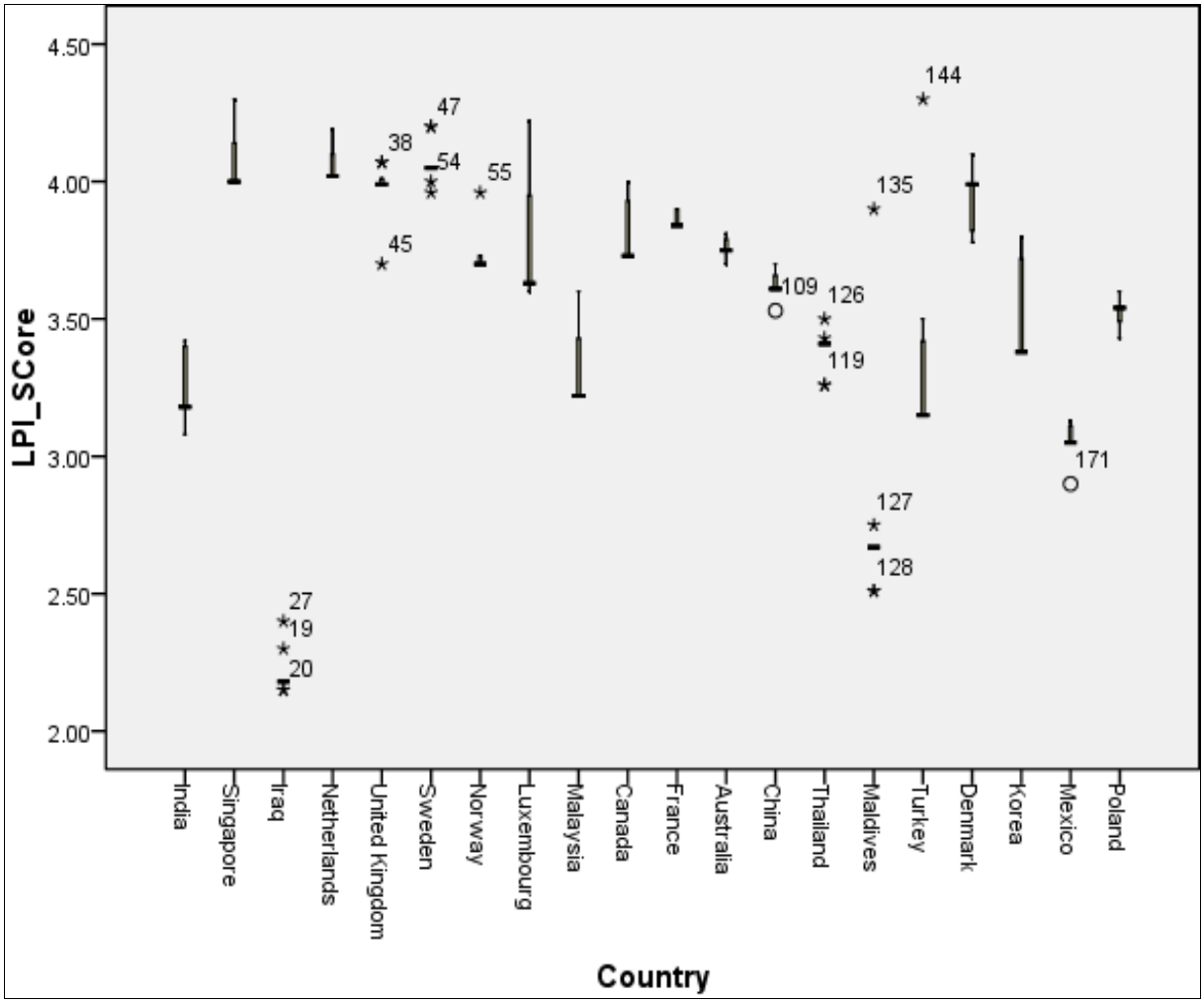

Fig 1: Country wise LPI score from 2023-2024

Table 2: Correlation between LPI score, GDP and GSR

	LPI_ SCore	GSR	GDP
LPI_ SCore	Pearson Correlation	1	-.116
	Sig. (2-tailed)		.122
	N	180	180
GSR	Pearson Correlation	-.116	1
	Sig. (2-tailed)	.122	
	N	180	180
GDP	Pearson Correlation	.670**	-.231**
	Sig. (2-tailed)	.000	.002
	N	180	180

The correlation value of 0.67 indicates strong positive correlation between GSR and LPI score whereas the GDP has low correlation with LPI.

Table 3: Model Summery

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.671[a]	.450	.444	.36524

a. Predictors: (Constant), GDP, GSR

ANOVA

MndRI	Sum of Squares	df	Mean Square	F	Sig.
Regression	19.320	2	9.660	72.415	.000[2]
Residual	23.611	177	.133		
Total	42.931	179			

a. Predictors: (Constant), GDP, GSR
b. Dependent Variable: LPI_SCore

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
MndRI	B	Std. Error	Beta	t	Ski.
(Constant)	3.131	.045		69.311	.000
GSR	1.151E-13	.000	.042	.725	.469
GDP	1.284E-5	.000	.679	11.854	.000

Dependent Variable: LPI_SCore

The p-value from ANOVA table signifies that there is a significant relationship between the dependent variable LPI score and the independent variables GSR and GDP. The R-square value of 45% indicates that the model is moderately fit. The relationship between LPI, GDP and GSR can be expressed as follows

Y = 3.131 +1.151E-13 GSR + 1.284E-5 GDP

Conclusion

The research findings underscore a significant relationship between a country's logistics performance (LPI) and its net trade balance (GSR). This connection indicates that logistics capabilities—such as infrastructure, customs efficiency, and quality of services—play a substantial role in influencing trade outcomes. The correlation analysis shows how closely related the Logistics Performance Index (LPI) and GDP are across countries. A significant and strong correlation suggest that countries with higher LPI scores have either increased GDP. This research demonstrates that logistics performance is a crucial factor in determining trade success, and improvements in logistics could offer a viable path for enhancing trade balances and supporting broader economic growth objectives. The findings advocate for a strategic focus on logistics enhancement as part of comprehensive trade and economic policies, especially in a globally interconnected economy where logistics efficiency can be a competitive advantage.

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