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Features Extraction Over the Years in International Logistics Performance Index

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Abstract: The importance of the logistics performance of companies, regions and countries to support decision-making is universally recognised, covering the rationalisation of supply chains, the optimisation of inventory management and promoting global collaboration. Efficient logistics integration with innovative technologies is crucial for prompt delivery and increased organisational performance. This study examines the correlation structure between Logistics Performance Index (LPI) indicators over several years. The LPI assesses global logistical performance by measuring factors such as the quality of commercial and transport infrastructure, the ease of customs procedures and the efficiency of customs clearance, among other aspects that influence the transnational flow of goods. Our results confirm the LPI as a longitudinal latent variable, characterised by its indicators, which demonstrate remarkable internal consistency. This consistency underpins the reliability of the LPI for assessing global logistics performance. Recognised as a valuable measure of logistics efficiency, LPI serves as a practical tool in business and politics, guiding strategic decision-making and improving the operational cost-benefit ratio and competitiveness of organisations.

keywords: Logistics Performance, LPI, Logistics Decision-Making, Feature Aggregation, Principal Component Analysis, Longitudinal

MSC2020: 62Hxx; 62H25; 62Pxx.

1 Introduction

The speed and efficiency with which companies transport goods across international borders, thanks to globalisation, have become fundamental characteristics of their global competitiveness. This encourages the continued development of performance measures such as the World Bank's Logistics Performance Index (LPI) [**?**], Global Competitiveness Index (GCI) [**?**], Global Enabling Trade Index (GETI) [**?**] and UNCTAD Liner Shipping Connectivity Index [**?**]. Access to these measures quickly, automatically and efficiently is crucial [**?**, **?**]. Globalisation has made the speed and efficiency of international goods transport fundamental to global competitiveness, encouraging the development of measures like the World Bankâs Logistics Performance Index (LPI), Global Competitiveness Index (GCI), Global Enabling Trade Index (GETI), and UNCTAD Liner Shipping Connectivity Index. LPI, measures the performance of countries logistics system and provides a guide for businesses and policymakers interested in global trade and international investments [**?**, **?**, **?**, **?**]. The LPI allows countries to assess their current logistics-related strengths and weaknesses, identifying the areas in which they need to improve,

and benchmark their performance against global standards, to enhance their international trade capabilities [**?**, **?**].

This paper seeks to validate the LPI as a measure of logistical performance by analysing key characteristics and relationships among its indicators. By recognising the LPI as a feasible and robust metric, it can be employed to inform strategic decision-making across business, logistics, and policy sectors, thereby enhancing operational efficiency and competitiveness on a global scale. For that Principal Component Analysis (PCA) is considered for extracting the essential feature in the data. Additionally, the paper tracks Portugal's LPI performance from 2007 to 2023, focusing on its changes and implications for logistics strategy. The structure considered is divided into four sections. In the first the theme and importance of the LPI index are presented, in the second the main concepts of PCA are highlighted, the third encompasses the data analysis and presents the results obtained, and the fourth consists of the conclusion and future work of the study.

2 Results and discussion

The LPI [**?**] is an aggregate index for a welfare evaluation of countries' logistics performance worldwide based on multiple variables. LPI has six key dimensions [**?**, **?**]: i) **Customs** Clearance Process: The efficiency of customs and border clearance processes; ii) **Infrastructure** Quality: The quality of trade and transport-related infrastructure, including ports, railroads, and roads; iii) Ease of Arranging **(International) Shipments**: The ease of arranging competitively priced shipments; iV)**Logistics Competence and Quality** of Services: The competence and quality of logistics services, such as transport operators and customs brokers; v)**Timeliness** of Shipments: The frequency with which shipments reach the consignee within the scheduled or expected delivery time; vi) **Tracking and Tracing**: The ability to track and trace consignments.

To identify the variables that most contribute to the countries' logistical performance, techniques for selecting or extracting key indicators can be used. In both cases, the aim is to retain the indicators that maximise the variance extracted from the original data. In [**?**], to ensure that the extracted characteristics were relevant and informative in relation to the 2023 Logistics Performance Index indicators, extraction techniques were used, in particular Exploratory Factor Analysis (EFA), using PCA in the JASP software. The present study considers LPI indicators over several years, being therefore a longitudinal approach, using the software R. This analysis is based on the values of the LPI indicators in the years 2007, 2010, 2012, 2014, 2016, 2018 and 2023. As the EFA carried out in [**?**] allowed the identification of a single factor, in this work a Principal Component Analysis (PCA) was carried out over the available years, considering one component. Assumptions for this techniques (EFA and PCA) are verified: (i) Sample dimension - The sample comprises between 139 and 160 countries (Table **??**), and there is no missing values. Therefore, the sample size is adequate for the analysis of the six indicators. (ii) Normality Assessment - Both the Mardia Test and the Energy Test were used, under the null hypothesis of multivariate normality. In some year Mardia's Test presented p values greater than 0.05, therefore, a multivariate normal distribution can be considered, but in most years none of the tests allows to confirm this assumption. (iii) Linearity – Pearson's Correlations between Indicators are significant at the 5% significance level, in addition, they are all high, exceeding the value of 0.8, suggesting a strong interdependence between them (multicollinearity). Consequently, the extraction of factors from these characteristics is justified and imperative, in order to exclude potential redundancies and increase the robustness of the analysis. (iv) Homoscedasticity – The standard deviation values of the indicators are close to and below 1, which suggests the existence of homoscedasticity and a relatively consistent distribution of data around the respective means for each indicator, over the years.

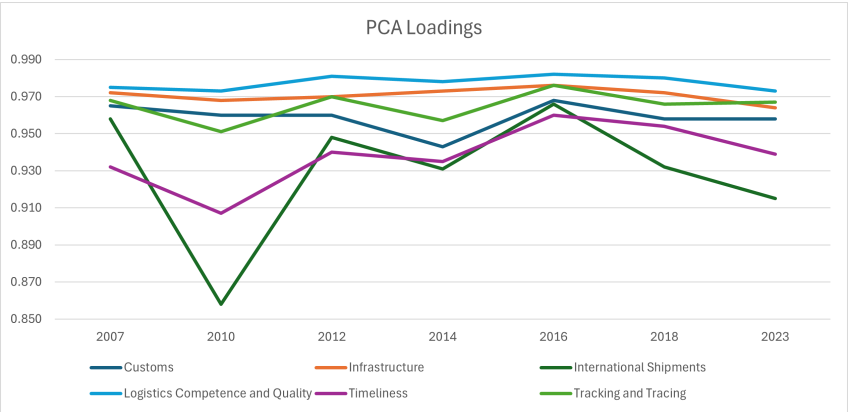

Figure 1: PCA Loadings across the years

Once the necessary conditions have been verified, PCA can be implemented to extract the principal component that maximises the retention of variance of the observed variables.

The Kaiser-Meyer-Olkin (KMO) Measure of Sample Adequacy (MSA) or Overal MSA and the MSA for each variable indicates the suitability of the variable for PCA.

Table 1: Kaiser-Meyer-Olkin and MSA

Year	**2007**	**2010**	**2012**	**2014**	**2016**	**2018**	**2023**
KMO - Overall MSA	0.93	0.92	0.94	0.92	0.94	0.94	0.93
Number of Countries	150	155	155	160	160	160	139

KMO ranges between 0.92 and 0.94, **??**, over the years and the individual MSA of each variable between 0.88 and 0.98. This all individual MSAs are greater than the 0.5 threshold, indicating that they are adequate for the analysis. Additionally, the overall MSA or KMO values suggests excellent suitability for applying PCA.

In determining the number of factors to retain by focusing on PCA eigenvalues exceeding 1 ([**?**]), a single factor was extracted over the years. The percentage of variance retained of these indicators over the years is between 87.8 and 94.4 (Table **??**). This means that all indicators contribute to the same latent variable, indicating a high level of correlation between them. Within this factor, *Logistics Competence and Quality* is always the indicator with highest loading. The behaviour of the loading's values across the time can be observed Figure **??** and are between values 0.86 and 0.98. The *Infrastructure* indicator presented the second highest value since 2007, but was surpassed by *Tracking and Tracing* in 2023. The *Customs* indicator has shown almost constant behaviour over the years, generally appearing in third or fourth position, in relation to loading values. The indicators with lower values were *Timeliness* and *International Shipments*, particularly in 2010. Since 2016, the loading's of all indicators have been decreasing.

Table 2: Explaned Variance and Reliability

Year	**2007**	**2010**	**2012**	**2014**	**2016**	**2018**	**2023**
Explaned Variance (%) - 1 factor	92.5	87.8	90.8	92.4	94.3	92.3	90.8
Reliability - Cronbach' α	0.983	0.970	0.982	0.979	0.987	0.982	0.978

The estimate Cronbach's α of the factor obtained across the time is between 0.970 and 0.987, indicating excellent reliability . This provides evidence of the excellent internal consistency of the latent variable. Cronbach's α of the extracted component obtained over time under analysis is between 0.970 and 0.987, indicating excellent reliability ([**?**]). This provides evidence of the excellent internal consistency of the latent variable over the years.

3 Conclusion and Future Work

In this study it is concluded that there is a strong correlation between all LPI indicators over the years, suggesting a good definition of the LPI as latent variable. This correlation structure remains almost unchanged over the time, with the main indicator always being the same over the years. In fact, the positioning of the loadings of all indicators is at values above 0.85, therefore all of them are very close to 1. The LPI also presents a notable internal consistency over the years, meaning the high level of correlation between these indicators, which implies a coherent and unified measurement of the latent variable, reinforcing the reliability and coherence of the LPI as a robust tool for evaluating logistics performance. This vision contributes to an understanding of logistics performance and can be generalized to organizations as a reference measure on a national and global scale, guiding the decision-making and strategic decisions with regard to the logistics performance of organizations, regions and countries.

A good suggestion for future work is to develop a logistics performance index for logistics companies and extending these concepts to the industrial level. This would be very useful for these companies. Another suggestion is to consider a Longitudinal approach to PCA, using for example the R package [**?**] and also a model based clustering and dimensionality reduction of mixed data [**?**] approach.

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