EXPLORING LOGISTICS PERFORMANCE INDEX USING I-DISTANCE STATISTICAL APPROACH

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Abstract: *The paper analysis the structure of the World Bank's Logistics Performance Index -LPI. . Weighting procedure applied to construct LPI is explored using a statistical I-distance technique. Based on LPI data, the importance of each variable is obtained and ranking of countries is performed. The results revealed that index based on I-distance better encapsulates six LPI indicators. Some discrepancies between LPI and I-distance based ranking, appear to be more significant among lower ranking countries.*

Keywords*: logistics performance evaluation, statistical analysis, country rankings.*

1. INTRODUCTION

Logistic performance index (LPI) is a monitoring instrument devised by World Bank in 2007 and has since been updated every two years. It is in fact a cross-country dataset providing information on logistic performance across 160 countries. LPI is developed to help countries in monitoring their logistic performance and define future development strategies that will support economic growth. It covers several key aspects such are perceptions of logistics environment, efficiency of customs, quality of transport and infrastructure, timelines of shipments in reaching destination, domestic logistics costs. The data for LPI are collected using web survey and structuralized questionnaire. Using principal component analysis (PCA), responses in form of scores are aggregated to a single index (Arvis et al., 2010). Results are disseminated through reports and online scoreboard for two types of indices. The first one is international LPI and reflects the state of play in an observed country based on the opinions of its main trade peers. The other is domestic LPI - in which respondents provide information on the logistics environment in the country where they work.

The main benefit of LPI is that it offers a comprehensive, open source cross-country data set that can be further exploited in logistic performance evaluation. For example Gogoneata (2008) used regression analysis and domestic LPI data to analyse the influence of chosen macroeconomic variables on logistics sector in Central and Eastern Europe countries. Dasan (2013) relied on LPI data to determine whether small and medium enterprises that trade internationally have better performance. Coto-Millán et al. (2013) proposed global dynamic aggregate production function to determine the contribution of logistics performance to world economic growth. Their findings were about how much the LPI increase can generate an increase of world economic growth. To determine the importance of logistic performance for EU exports, Puertas Medina et al. (2013) used LPI data and gravity equations.

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Methodological framework of LPI has however, not been much questioned. One example is the work of Jane and Laih (2012) who used LPI to evaluate their own index *Rb,d* and concluded that *Rb,d* resolves the problem of integrating reliability into logistics performance, which was emphasized in 2010 LPI report.

In this paper we deal with weighting of indicators that constitute international LPI. The construction of composite indicators (CI) has several steps and each of them entails a proper method which heavily affect the ranking results. As indispensable part of index construction, weighting and aggregation methods have a substantial effect on the outcome of the composite indicator (Saisana and Tarantola, 2002; Freudenberg, 2003; Singh et al., 2009; Hudrliková, 2013). In this paper we examined the I-distance method (Ivanović, 1973; Ivanović and Fanchette, 1973), as an alternative to principal component analyses (PCA) used in LPI. By using a statistical I-distance technique, the importance of each variable (LPI indicator) is obtained and ranking of countries is further appraised.

The paper is organized as follows. In the next section we briefly recall the methodology used to construct international LPI. Section three is about I-distance statistical method and its appliance in the domain of composite indicators. The subsequent section contains results of applying I-distance on LPI data and discussion. The paper ends with concluding remarks.

2. INTERNATIONAL LPI METHODOLOGY

Logistic performance index (LPI) is based on the survey of perception of operators in charge of moving and trading goods on six key performance topics. In 2016, 1,051 logistics professionals participated in the survey for the LPI (WB, 2016). The international LPI is based on qualitative data - respondents' opinions. For each country, collected data (answers) are aggregated into single score (LPI) using PCA. LPI results as well as full data sets are available for 2007, 2010, 2012, 2014 and 2016. World Bank provides various online visualisations tools allowing to explore global LPI rankings and countries' scorecards. It also allows to compare countries performance against: top performer for the observed year; country's region and income group; top performer in region and top performer in income group.

2.1 Indicators and data

LPI includes six indicators categorized as input or output indicators (WB, 2016). The input indicators indicate areas for policy regulation, while the output indicators are about service delivery performance (Table 1).

Table 1. Indicators for international LPI (authors' compilation from WB, 2016)

	Topic	Indicator	Rated from- to	Category
1.	Customs	The efficiency of customs and border management clearance	"very low" (1) to "very high" (5)	input
2.	Infrastructure	The quality of trade and transport infrastructure	"very low" (1) to "very high" (5)	input
3.	Shipments (international)	The ease of arranging competitively priced shipments	"very difficult" (1) to "very easy" (5)	output
4.	Services quality	The competence and quality of logistics services	"very low" (1) to "very high" (5)	input
5.	Tracking and tracing	The ability to track and trace consignments	"very low" (1) to "very high" (5)	output
6.	Timeliness	The frequency with which shipments reach consignees within scheduled/ expected delivery times	"hardly ever" (1) to "nearly always" (5)	output

Indicators for LPI are developed based on systematic research, both empirical and qualitative studies i.e. practical experiences of logistic providers. The responding countries are selected based on the most important export and import markets of the country where the respondent is

located, and, for landlocked countries, on neighbouring countries that connect them with international markets. From 2012 the countries are chosen using Uniform Sampling Randomized (USR) approach in order to include responses from countries with lower trade volumes as much as possible.

Qualitative data are in form of scores since the respondents evaluate six core dimensions on a scale from 1 (worst) to 5 (best) with proper linguistic terms (see Table 1).

2.2. Constructing international LPI - Normalisation, weighting and aggregation

The international LPI is constructed from six indicators (Table 1) on the basis of principal component analysis (PCA). Before being subjected to PCA, scores (answers to questions 10-15) are averaged and normalized using standardization (z-scores) approach.

The results from all PCP rounds (LPI editions) indicate that a single principal component can be taken to encapsulate the data for all six topics (based on Kaiser Criterion and the eigenvalue scree plot). This component accounts for 92 percent (data from 2016 LPI edition) of the variation and represents the international LPI.

The next step is weighting and aggregation using PCA. LPI weights are obtained based on the maximization of the percentage of variation in the LPI's original six indicators that is accounted for by the summary indicator. The component loadings reflect the weight given to each original indicator in constructing the international LPI. Once component loadings are obtained the international LPI is calculated simply – the normalized scores of each of the six indicators is multiplied by their normalized component loading (Table 2) and then summed.

Table 2: Weights (component loadings) for international LPI based on PCA approach (authors' compilation from LPI reports)

	2016	**2014**	**2012**
Indicator	*w*	*w*	*w*
Customs	0.41	0.40	0.41
Infrastructure	0.41	0.42	0.41
Shipments (international)	0.41	0.40	0.40
Services quality	0.41	0.42	0.42
Tracking and tracing	0.41	0.41	0.41
Timeliness	0.40	0.40	0.40

It can be noted that the loadings exhibit similar values, thus the international LPI is close to the simple average of the six indicators. Also the weights remain steady across LPI editions (two-year reports) indicating comparability.

It is also of importance to stress that sampling errors are controlled by confidence intervals. That is, a statistically significant improvement in a country's performance is not accounted unless the lower bound of the country's current LPI score (e.g. in 2014) exceeds the upper bound of its previous LPI score (e.g. in 2012).

2.3. Some methodological issues of LPI and the scope of the study

Some notes on LPI results should be considered. For instance, the validity of LPI results in poor countries may fail to capture the performance of national logistic providers that often have special arrangements with government agencies (WB, 2016). Similar validity issue goes for isolated island countries, for which LPI cannot reflect the reforms associated with transit routes.

One more issue is the reliability as the part of LPI. Although emphasized this feature not resolved within the LPI and requires additional performance indicators to address it (as the

index developed by Jane and Laih (2012) that models the real-world logistics systems as stochastic flow networks).

Additional questionable LPI feature is its validity as a ranking tool. As highlighted in LPI methodological note (WB, 2016), due to inevitable sampling errors (that go with this kind of survey samples) the rankings may be elusive for decision makers.

To test the validity of LPI ranks we propose to rely on Composite I-distance Indicator (CIDI) methodology. This approach contributes to more reliable approach in defining weighting scheme and thus obtaining more stable results using the statistically sound framework (Dobrota et al., 2016).

3. I- DISTANCE AND COMPOSITE INDICATORS

Composite I-distance Indicator (CIDI) methodology is recognized as useful for obtaining more stable ranking (see Dobrota et al., 2015), and its roots can be traced down to I-distance method (Ivanovic, 1973). In the process of constructing indexes, I-distance can be used to obtain weights for indicators. To achieve this it is necessary to calculate I-distances and to obtain I-distance rankings accordingly. I-distance is in fact a metric distance in an n-dimensional space. The square I-distance between entities $e_r=(x_{1r}, x_{2r}, \dots x_{kr})$ and $e_s=(x_{1r}, x_{2r}, \dots x_{ks})$ is calculated as in (1) (Ivanovic & Fanchette, 1973):

$$D^2(r,s) = \sum_{i=1}^{k} \frac{d_i^2(r,s)}{\sigma_i^2} \prod_{j=1}^{i-1} (1 - r_{ji.12\dots j-1}^2) \tag{1}$$

where $X^T=(X_1, X_2, \dots X_n)$ is the selected set of indicators that characterize the entities, $d_i(r,s)$ is the discriminate effect, σ_i is the standard deviation of X_i and $r_{ji,12\dots j-1}$ is a partial correlation coefficient between *Xi* and *Xj* (Jeremic et al., 2011). The Pearson correlations between the I-distance and input indicators values is calculated to test stability of each of the compounding indicators. The weights are computed in a way that values of correlations are divided by the sum of correlations (2):

$$w_i = \frac{r_i}{\sum_{j=1}^{k} r_j} \tag{2}$$

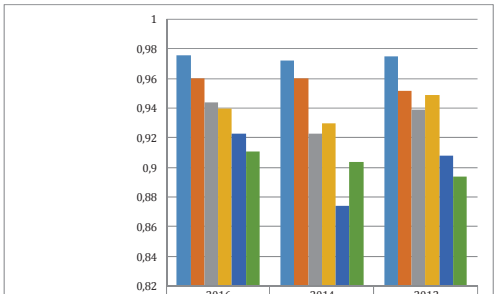
where r_i, $(i=1\dots k)$ is a Pearson correlation between i_{th} input variable and I-distance value. The final sum of weights equals one (Dobrota et al., 2015). After obtaining weights, they are incorporated into LPI indicators framework and aggregated CIDI score is obtained.

4. EXPLORING INTERNATIONAL LPI WITH CIDI

We applied CIDI approach and calculated new country rankings for years 2016, 2014 and 2012. The data for LPI indicators are from *full LPI data set* for last three LPI rounds and are provided online from World Bank.

We can first discuss about the importance of each indicator, based on the Pearson correlation coefficient between I-distance and each indicator (Figure 1). We can conclude that all the indicators show high correlation with I-distance. *Customs* and *Infrastructure* remained stable across the observed years while there were some changes regarding the importance of the rest of the indicators. *Shipments* and *Service quality* switched places in 2014 and 2012. The same goes for *Tracking&Tracing* and *Timeliness* in 2014. Compared to the weights obtained based on

component loadings (Table 2) we can say that unlike LPI approach which employs almost equally weighting scheme, our results show that weights should be more discriminating.



	2016	2014	2012
Customs	0,976	0,972	0,975
Infrastructure	0,96	0,96	0,952
Shipments (international)	0,944	0,923	0,939
Services quality	0,94	0,93	0,949
Tracking and tracing	0,923	0,874	0,908
Timeliness	0,911	0,904	0,894

Figure 1: Correlation between I-distance and international LPI indicators

I-distance based rankings are more accurate. Namely, the international LPI accounts for 92 percent of the variation in the six components (for 2016), while this value for I-distance based LPI is 94 percent (meaning that our solution better encapsulates six LPI indicators).

The rankings obtained by CIDI are very similar to the ones obtained on the basis of LPI. For example the position of Serbia remained stable across all observed years based both on LPI and CIDI results. Figure 2 is a box-plot that represents discrepancies between LPI and I-distance based rankings. Existing discrepancies appear more among lower ranked countries. Venezuela is with the highest sum of difference mostly due to 2012 results.

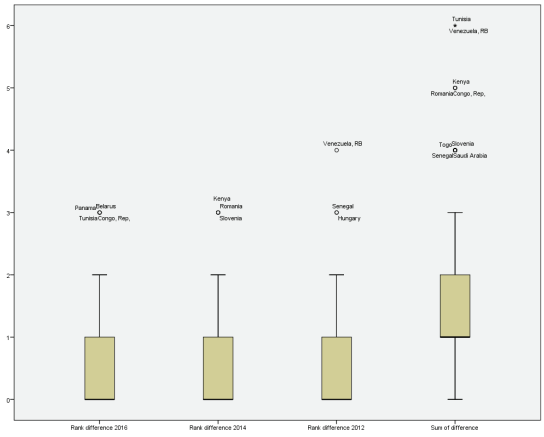


Figure 2: Discrepancies between LPI and I-distance based rankings

6. CONCLUSION

In this paper we explored weighting and aggregation used to construct international LPI. Composite I-distance Indicator (CIDI) methodology was used to obtain new index and compare it with international LPI. The results revealed that there are some discrepancies in ranking for less successful countries. Also it was found that CIDI approach offers better validity of results reflected in higher percentage of variation extracted from six LPI indicators. Accordingly, CIDI methodology can be considered as a viable alternative for international LPI.

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