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COMPONENTS OF THE POLISH LPI IN RELATION TO MACROECONOMIC VARIABLES. COINTEGRATION ANALYSIS

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Purpose: The aim of the article is to analyze Poland's logistics potential measured by the means of the LPI (Logistics Performance Index). The impact of trade volume, infrastructure development and service quality on individual LPI components was assessed. Estimating the relationship between the components of the Polish LPI index and macroeconomic variables enables the assessment of the strength of the relationship and sensitivity to the economic situation. It allows to draw conclusions about possible areas that are more sensitive or require repair. It also enables to indicate how the economy influences the TSL sector (Transport–Shipping–Logistics).
Design/methodology/approach: The analysis was carried out using the rules and methods of time series cointegration, which enable the analysis of long- and short-term relationships. This enabled the identification of areas most sensitive to the influence of particular factors. To obtain consistent time series, interpolation methods were also used.
Findings: The development of infrastructure and an increase in the level of services has a positive impact on all aspects measured by LPI components. In turn, the increase in trade exchange, as an increase in demand for the TSL sector, affects four of the six components. In two cases, border services and on-time delivery, the relationship is negative. This highlights the main points limiting the growth of LPI ratings and indirectly limiting trade and economic development of Poland.
Research limitations/implications: Limited data availability influenced the choice of method used in the study. Moreover, short time series and data interpolation used in the study may result in the inaccuracy of estimations.
Practical implications: Econometric analysis indicates weaknesses in the Polish logistics sector. Improvements in customs regulations and expansion of infrastructure may improve the functioning of the TSL sector. It should be of particular interest to policy makers, for which economic growth and the LPI rating should be very important.
Originality/value: This is the first paper that uses econometric tools to compare the components of LPI with macro variables.
Keywords: Components of Logistics Performance Index (LPI), Data interpolation, Cointegration analysis.
Category of the paper: Research paper.

1. Introduction

Trade and transport play a pivotal role in driving economic development and fostering national competitiveness. Efficient logistics serves smooth movement of goods and services, reducing costs, improving market access, and enhancing overall economic efficiency. Investments in infrastructure, technological advancements, streamlined customs procedures, and policy reforms aimed at improving logistics and trade facilitation are crucial for enhancing national competitiveness. Countries that prioritize and invest in these areas often experience accelerated economic growth, improved global competitiveness, and better integration into the global economy.

The article analyzes six components of the Logistics Performance Index (LPI) and their relationship to macroeconomic variables affecting the assessment and functioning of the entire logistics system in Poland. Three key macroeconomic variables were mainly assessed: the volume of international exchange of goods, expenditure on infrastructure and prices. The analysis was carried out using the rules and methods of time series cointegration, which enable the analysis of long- and short-term relationships. This enabled the identification of areas most sensitive to the influence of particular factors. To obtain consistent time series, interpolation methods were also used.

2. Methods

World Bank's LPI is a crucial tool for evaluating and comparing the trade and transport facilitation of different countries. It provides a comprehensive framework to assess various dimensions of logistics performance, including customs efficiency, infrastructure quality, ease of arranging shipments, timeliness of shipments, and more.

The methodology used in constructing the LPI score involves principal component analysis, a statistical technique that simplifies and condenses a dataset's dimensionality. Normalizing scores by averaging them across respondents and then standardizing them helps in creating a comparable measure across different countries.

The resultant LPI score, derived from these components, serves as a comprehensive indicator, enabling international comparisons and offering insights into a country's overall logistics performance. It is a valuable tool for policymakers, stakeholders, and businesses to identify areas of improvement and formulate targeted strategies to enhance trade and transport facilitation.

The LPI consolidates various aspects crucial for evaluating logistics sector performance into a single composite measure. These six core components provide a holistic view of a country's logistics and trade facilitation:

1. **Customs**: Focuses on the efficiency of customs and border management clearance processes, which greatly impacts the speed and ease of goods movement across borders.
2. **Infrastructure**: Assesses the quality of trade and transport infrastructure, including roads, ports, railways, and airports, which are essential for efficient logistics operations.
3. **Shipment**: Evaluates the ease of arranging competitively priced international shipments, reflecting the accessibility and affordability of logistics services.
4. **Equality**: Measures the competence and quality of logistics services, crucial for ensuring reliable and efficient movement of goods.
5. **Timeliness**: Considers the frequency with which shipments reach their destinations within scheduled or expected delivery times, reflecting reliability and predictability in logistics operations.
6. **Tracking**: Assesses the ability to track and trace consignments, which is important for transparency and accountability within the supply chain.

The LPI's ability to analyze these components helps pinpoint areas for improvement within logistics and trade systems. By understanding the strengths and weaknesses in these different aspects, countries can develop targeted strategies and policies to enhance their overall trade and transport efficiency.

The publications of the World Bank clearly emphasize the significant relationship between the level of economic development of the assessed countries and the overall assessment expressed in the LPI. The logistics system of economies with a higher level of development is rated much higher. This leads to frequent analyzes and attempts to assess the relationship between the LPI and commonly used measures of economic development, such as GDP. Conclusions are also drawn that improving the LPI assessment may lead to an increase in trade and, therefore, economic growth (Ojala, Celebi, 2015).

The main benefit of the LPI is that it offers a comprehensive, open-source cross-country data set that can be further exploited in logistic performance evaluation. Desan (2013) relied on the LPI data to determine whether small or medium enterprises that trade internationally have better performance. Coto-Millan et al. (2013) proposed global dynamic aggregate production function to determine the contribution of logistic performance to world economic growth. Gunter and Coskun (2012) analyze the relationship of economic and social factors with logistics performance of countries. Tundys (2011) uses the LPI as useful tool and instrument for identifying the potential of the region and for the indication of bottlenecks in the logistics area in the international context. Gogoneata (2008) used regression to analyze the influence of chosen macroeconomic on a domestic LPI in Central and Eastern European countries. Grzelakowski (2018) analyzed the transport-oriented factors and conditions of logistics macro-systems development as integral components of the global logistics system with special

attention paid to the Polish logistics system. He identified transport infrastructural and regulatory barriers hindering effectiveness and efficiency of the Polish logistics system. It was to indicate its development potential by reviewing it with logistics macro-systems of neighboring countries and leading countries in the global scale. The universality of the LPI indicator can also be a source of analyzes in more general areas, e.g., human development (Varma, Shah, 2021).

More detailed analysis of the LPI components for individual countries can be a very helpful policy tool and support economic development. Studies that compared not only the main LPI index but also its components were conducted, e.g., for Russia (Andriianowa, 2017), Bulgaria (Varbanowa, 2017), Uzbekistan (Yusufkhonov et al. 2021) or Poland (Niedzielski et al., 2021; Sowa, Wysocka, 2012). This study hypothesized that analyzing the relationship between macroeconomic variables and specific LPI components could identify sensitive sections of logistic system. Areas in which infrastructure investment policy should be most effective in improving the functioning of the TSL sector and elements of the system that work properly or fail because of increased trade or changes in the quality of services.

The proposed study puts forward the assumption that the rating of the LPI logistics system depends on macroeconomic variables directly related to the logistics process. Each of the six LPI components is sensitive to specific variables, such as the volume of trade, the quality and development of infrastructure and competitiveness of the services offered (1):

$$LPI_j = f(Trade; Infrastructure; Services) \tag{1}$$

where LPI_j are $j = 1, \ldots, 6$ components of the LPI.

There are many factors that can be distinguished, but due to the length of the sample and the measurability of some effects, the study focuses only on these three most important elements.

A factor that directly influences LPI is the volume of transported products (*Trade*), the impact of which may have a stimulating or limiting effect. On the one hand, the increase in the volume of transported cargo causes an increase in demand for logistics services and has a positive impact on the development of the logistics system, the quality of services and LPI components. On the other hand, in the event of system failure, excessive transport volume or failure to keep up with global competitors, it leads to discouragement of suppliers, drop in demand, and cased lower LPI rating. The study used the sum of the volume of exports and imports of goods (constant prices for 2015) as a measure of trade volume.

The basic factor influencing the operation of logistics is the level and development of the generally understood logistics infrastructure (i.e., buildings, civil engineering structures, machinery and the IT technologies used). The assessment of the infrastructure itself is also influenced by the ability to handle the volume of trade and the entire set of services related to its maintenance and efficiency. There is no uniform measure that would reliably reflect each of the factors, let alone and/or all these factors together. The study assumes that the main factor influencing the development and general level of transportation facilities are investment

expenditures in land and sea structures. For this reason, to assess infrastructure data of the volume of construction and assembly production of civil engineering facilities were used (constant prices for 2015).

Even more difficult to measure and evaluate is the overall level and quality of logistics services. While effectiveness can be measured by the efficiency of the transport and warehousing services sector, this value cannot be a measure of quality in the opinion of respondents. The study assumed that in a highly competitive market such as the logistics market in Poland, price increases best reflect the increase in the quality of services offered. For this reason, the value-added deflator in the transport and warehousing services sector (2015 = 1) was used.

One of the research hypotheses was that the variables are integrated I(1) and the cointegration analysis will allow to identify the relationship between LPI components and selected macro categories. Statistical tests indicated the non-stationarity of the analyzed time series[1]. Cointegration analysis methods allow to identify long- and short-term relationships. The two-stage Engel-Granger procedure was used in the estimation. The general form of models for individual LPI components can be written as follows (2):

$$\Delta LPI_j = \alpha_j\left(\beta_{0j} + \beta_{1j}t_{-1} + \beta_{2j}i_{-1} + \beta_{3j}p_{-1}\right) + \gamma_{1j}\Delta t + \gamma_{2j}\Delta i + \gamma_{3j}\Delta p \qquad (2)$$

where:

t – logarithm of sum of export and import of goods volume,

i – logarithm of volume of construction and assembly production of civil engineering facilities,

p – logarithm of value-added deflator in the transport and warehousing services sector,

α_j – Error Corection Term of *j*-th LPI component,

β_{kj} – *k*-th long-term relation of *j*-th LPI component,

γ_{kj} – *k*-th short-term relation of *j*-th LPI component.

Similar specification of equation (2) was applied to all LPI components. This procedure was aimed at statistical verification of relationships that, despite the emphasis placed on selected elements of the logistics system. It was assumed that the assessment of the LPI components depends on all the distinguished factors. For example, the efficiency of customs and border management or the assessment of infrastructure quality is also influenced by trade, the overall quality of services and the level of infrastructure utilization.

3. Results

3.1. LPI data and interpolation results

The LPI and its components were published for 2007, then every two years between 2010 and 2018, and finally because of the pandemic the last publication was for 2022. Due to irregularities in published rates, the data was interpolated into an annual data set. An example of the use of data disaggregation methods for quarterly to monthly data can be found in Welfe and Karp (2017). Methods used to estimate data for the years between published values were linear, log-linear, cubic spline, and cardinal spline.

The discrepancies between the linear and cubic spline interpolation methods were most significant in the sample intervals between 2007-2010 and 2018-2022 (the furthest periods between publications). Despite these discrepancies, the differences in the LPI didn't exceed 0.07p (Figure 1). This suggests that while there were variations in the estimated values obtained from different interpolation methods, these discrepancies were within a relatively small range and might not significantly impact the overall interpretation of the LPI components.

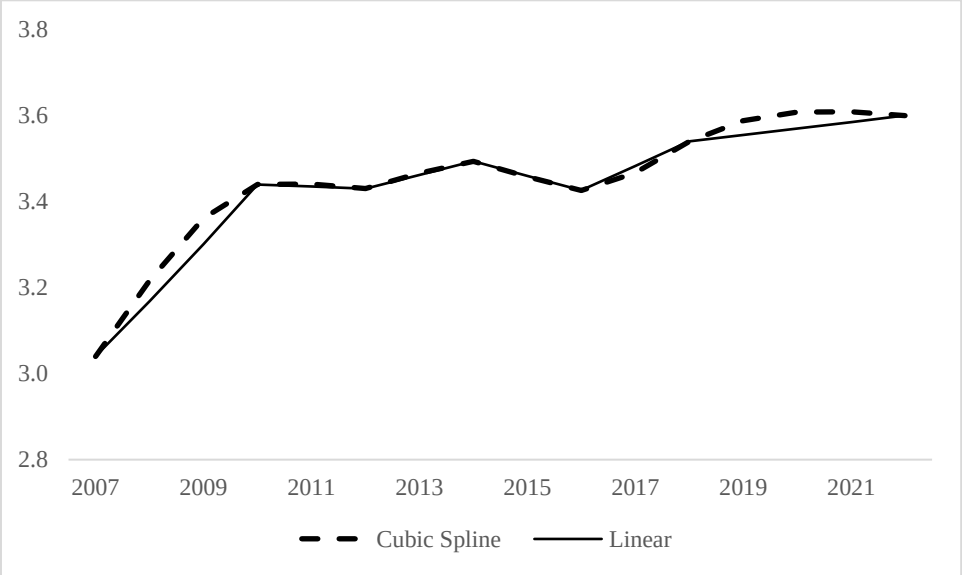

Figure 1. LPI interpolation results.

Source: own calculations.

In the case of individual LPI components, the largest discrepancies were obtained between the interpolation results for Timelines, which exceeded 0.2 points for 2009, and for Shipment, which slightly exceeded 0.1 points in 2019 (Fig. 2). The choice of interpolation method can influence the accuracy and smoothness of the estimated values, particularly when dealing with sparse or irregularly sampled data points. The fact that the differences remained within a limited range indicates that despite variations in the methods used, the overall trend and interpretation of the LPI might not be substantially affected.

The differences in the obtained results resulting from the interpolation methods used were insignificant and negligible. Therefore, in further analyses, the results were presented only for interpolation using the cubic spline method.

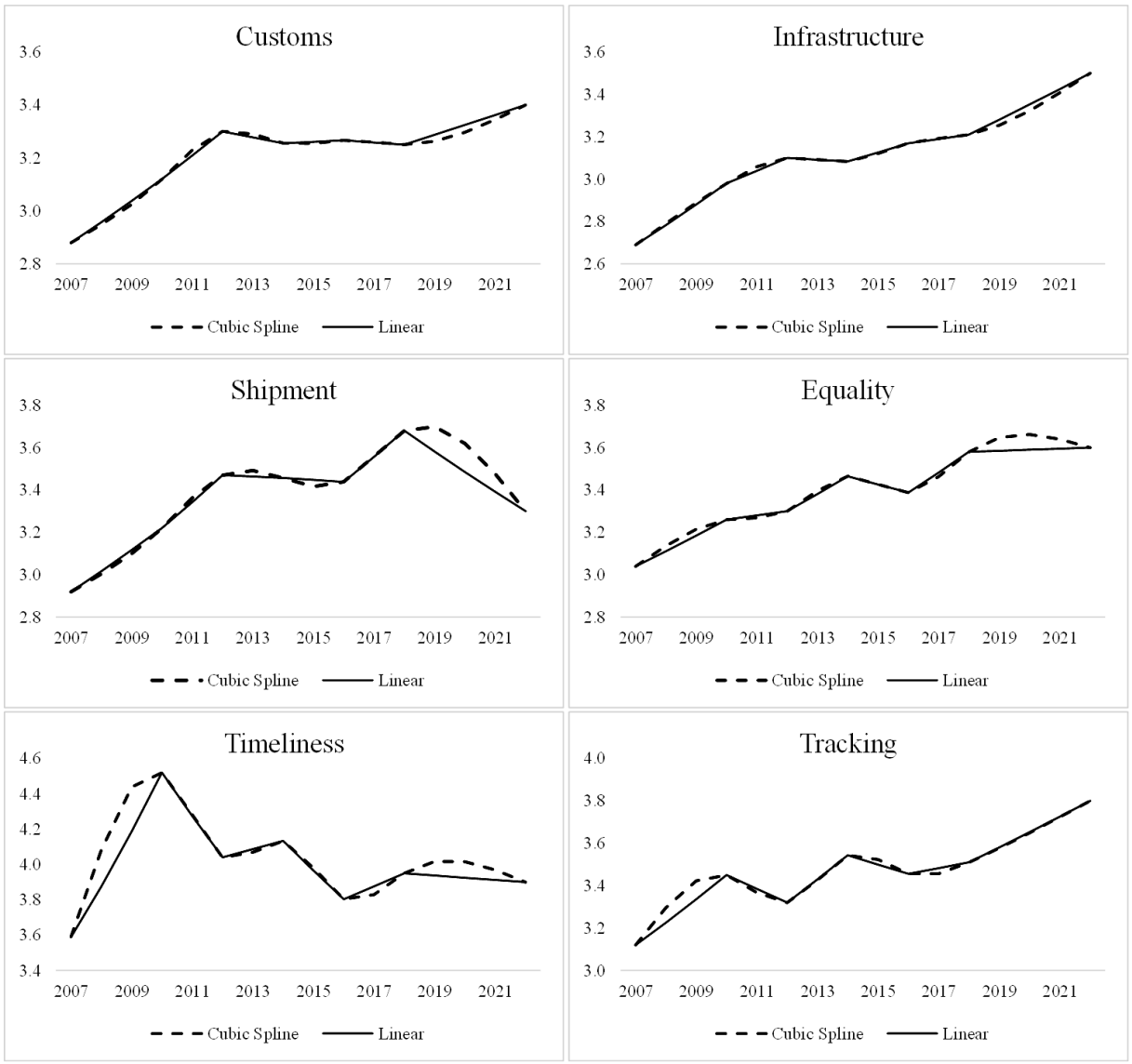

Figure 2. Interpolation results of the LPI components.

Source: own calculations.

The overall LPI increased during the period under review. Poland advanced from 40th position in 2007 to 26th position in 2022. Most components of the LPI index showed an increasing trend.

The most significant and visible growth can be observed in the Infrastructure rating, which increased by as much as 0.8 points to 3.5 in 2022. Poland's dynamic development, construction of expressways, expansion of sea and airport ports and modernization of the entire logistics infrastructure were appreciated by respondents. Customs, Equality and Tracking scores also increased during this period. After increasing in 2007-2018 to the level of 3.7, in the 2022 study the Shipment indicator dropped significantly to 3.3. It can be assumed that the assessment is

the result of global turmoil, in particular the pandemic and the war in Ukraine, as other data do not confirm such a decline.

A clearly different picture is associated with Timeliness. The high score that Poland received in 2010, ranking second in the world with a value of 4.52, proves the very efficient Polish logistics system. However, the Timeliness rating has been systematically decreasing since 2010 to 3.9 in 2022. This decline does not represent a decline in local service quality, but rather reflects the expected delivery times and increased logistics efficiency in other countries compared to Poland. Despite this decline, Polish punctuality is still rated very highly. This component was still the highest compared to other components of the Polish LPI.

Table 1.
Correlogram of the LPI and components

	LPI	**Customs**	**Infrastru.**	**Shipment**	**Equality**	**Timelin.**	**Tracking**
LPI	1						
Customs	0.90	1					
Infrastructure	0.93	0.95	1				
Shipment	0.90	0.91	0.96	1			
Equality	0.90	0.81	0.91	0.95	1		
Timeliness	**0.60**	**0.34**	**0.29**	**0.23**	**0.26**	1	
Tracking	0.93	0.76	0.83	0.78	0.89	**0.57**	1

Source: own calculations.

The differences in the impact and relationships between the LPI and its components are also illustrated in the correlation table (Table 1). What is particularly noticeable is the low correlation between Timeliness and the other components.

3.2. Estimation results

Six models were obtained for each LPI component. The results are presented in Table 2. The estimates of the parameters of long- and short-term relationships are semi-elasticity. Of particular importance is the statistically significant long-term relationships (ECT) and the stationarity of all residuals, which confirms cointegration of variables in every case. As follows from testing the hypothesis regarding nonstationarity, all stochastic processes generating the variables used in the models are integrated at the first degree I(1). All ECT estimates range from 0.65 to 0.94, which indicates a relatively quick adjustment to long-term relations.

Table 2.
Estimation results (The t-statistic values are shown in parentheses)

	Explanatory variables						
		Trade	**Investm.**	**Prices**	**Trade**	**Investm.**	**Prices**
LPI component	ECT	Long-term relationships			Short-term relationships		
	$\hat{\alpha}_j$	$\hat{\beta}_{1j}$	$\hat{\beta}_{2j}$	$\hat{\beta}_{3j}$	$\hat{\gamma}_{1j}$	$\hat{\gamma}_{2j}$	$\hat{\gamma}_{3j}$
Customs	***-0.65***	***-0.16***	***0.27***	***0.51***	*0.05*	*0.10*	*0.30*
	(-6.47)	*(-1.29)*	*(2.22)*	*(2.47)*	*(0.77)*	*(2.54)*	*(4.41)*
Infrastructure	***-0.82***	***0.23***	***0.31***	***0.36***	*0.34*	*0.21*	*0.40*
	(-2.87)	*(2.71)*	*(3.55)*	*(2.42)*	*(2.87)*	*(2.79)*	*(3.45)*

Cont. table 2.

Shipment	***-0.91*** *(-4.62)*	***0.47*** *(2.20)*	***0.62*** *(3.20)*	***-0.10*** *(-0.28)*	*0.59* *(3.27)*	*0.55* *(5.60)*	*-0.56* *(-3.31)*
Equality	***-0.74*** *(-3.08)*	***0.35*** *(3.41)*	***0.23*** *(2.30)*	***0.27*** *(1.57)*	*0.11* *(0.85)*	*0.22* *(3.01)*	*0.36* *(2.28)*
Timeliness	***-0.94*** *(-3.04)*	***-1.33*** *(-3.87)*	***0.94*** *(2.71)*	***0.24*** *(0.41)*	*-1.10* *(-2.12)*	*1.14* *(3.32)*	*0.44* *(0.90)*
Tracking	***-0.67*** *(-2.05)*	***0.24*** *(1.86)*	***0.25*** *(2.03)*	***0.29*** *(1.35)*	*0.42* *(2.01)*	*0.16* *(1.35)*	*0.69* *(3.34)*

Source: own calculations.

Construction and assembly production of land and maritime infrastructure facilities is the only variable that is largely subjected to political decisions. Therefore, it can be treated as an instrument. It is interesting that both the estimates of long- and short-term relationships mean that the increase in expenditure on the construction and development of infrastructure has a positive impact on all LPI components. Even those relating to regulation and evaluation of the effectiveness of services. The change in infrastructure development expenditure has the greatest impact on Timeliness, followed by Shipment. In turn, the change in the level of investment outlays does not have a dominant impact on the Infrastructure ranking. All three explanatory variables of the model determine this ranking to a similar extent. Even the price impact is the strongest. This indicates that the infrastructure level ranking is basically most dependent on services ensuring the correctness and efficiency of its operation. Therefore, better infrastructure also requires better service, which is accepted and involves an increase in costs.

Generally, prices, as an indicator relating to the assessment of the quality of logistics services, indicate a positive relationship with most LPI components. Only in the case of Shipment this impact is negative. This is justified because in this component the World Bank respondents are explicitly asked to assess shipping costs. Therefore, in this case, prices cannot be an assessment of the quality of services but refer directly to service costs and both the long- and short-term impact is negative.

Trade, as the volume of exported and imported goods, is a demand factor and positively affects the development and ranking of four of the six LPI components. The growth in trade exchange is the strongest driver of the Shipments rating, both in the long and short term. In the case of Customs and Timeliness, this impact is negative. The results obtained indicate the emergence of bottlenecks in these logistic areas. The increase in trade leads to overload and reduced efficiency of the logistics system, which cannot keep up with the volume of orders, which is reflected in the LPI assessments and parameter estimates.

Particularly noteworthy is the fact that Timelines, which have the highest ranking in the Polish LPI, are the most sensitive to changes in the volume of trade and investment expenditures (highest semi-elasticities). This leads to the conclusion that, at least in terms of on-time deliveries, the functioning of the Polish TSL sector may be seriously threatened if expenditure on infrastructure development does not keep pace with the increase in economic openness.

4. Conclusions

Interpolation of the LPI and its components allows obtaining consistent time series that were used for further analyses. They enable several methods that cannot be used for the output data. At the same time, it should be emphasized that in the analyzed case the choice of interpolation method has a negligible impact on the results and conclusions obtained.

The use of cointegration methods enabled the estimation of long- and short-term relationships. This confirmed the initial research hypothesis that the variables are integrated and the cointegration analysis should allow identifying the relationship between the LPI components and selected macro categories. The results indicate a strong and clear impact of infrastructure expenditure on the assessment of Poland's logistics system. At the same time, the further increase in international exchange and the flow of goods currently indicates two LPI components whose functioning may limit the efficiency of the logistics system, i.e., Customs and Timeliness. The result may provide an indication to policy makers which aspects of the functioning of the logistics system are failing in the respondents' opinion. These are places where improving efficiency can bring the greatest benefits for TSL services, the growth of trade and the entire economy.

Due to the short-time series, the analysis of the LPI components for Poland does not consider more factors. In particular, the set of explanatory variables should be expanded to include macro categories describing the world situation and the international climate. The LPI assessment and the final ranking depend on the subjective impressions of respondents who compare different markets.

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Footnotes

In most cases, the tests clearly indicate the non-stationarity of the series used in the study. Due to the low power of tests for small samples, it was assumed that all series were non-stationary. Ultimately, the estimation results confirmed the cointegration of the variables.