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LONG-TERM SOLVENCY AND SUSTAINABLE DEVELOPMENT OF LOGISTICS SECTOR – EVIDENCE FROM POLAND

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Purpose: The paper's primary goal is to assess the impact of long-term solvency on the logistics sector's sustainable development in Poland from 2008 to 2022.
Design/methodology/approach: To verify the research hypothesis, we created the synthetic indicators of sustainable logistics development and developed models using the Classical Least Squares Method (OLS), Vector Autoregression (VAR) and Seemingly Unrelated Regression (SUR).
Findings: The research results show that compliance with the golden financial rule is statistically significant for the sustainable development of the logistics sector. Moreover, it has a direct impact on the economic and social pillars.
Research limitations/implications: The selection of indicators for the research sample and the estimation methods limit the analysis.
Practical implications: Maintaining an appropriate financing structure for logistics sector companies is crucial, and ensuring compliance with the golden financial rule is important for the sustainable development of companies.
Social implications: The research results are important from the point of view of the development of the logistics sector in the social and ecological aspects, and reducing the sector's emissions should lead to improved conditions and quality of life for communities.
Originality/value: The paper's novelty is determining the impact of the golden rule of financing on the sustainable development of logistics.
Keywords: financial analysis, long-term solvency, sustainable development, logistics sector.
Category of the paper: research paper.

1. Introduction

Sustainable development is determined by improving the current generation's quality of life without losing future generations' ability to function freely and well. It requires the involvement of states, state entities, organizations and institutions, enterprises and ordinary people.

It is especially important to engage in green and social activities of enterprises. Companies are extremely important for economic growth, employment rates, and improving the quality of life of citizens and on the other hand, they are one of the main entities that cause pollution of the natural environment through their activities.

Logistics, recognized as a pivotal driver of economic development, has emerged as a dynamic force propelling the rapid growth of both national and regional economies (An et al., 2024; Mačiulis et al., 2009). At the same time, the future of logistics companies and their capacities (development opportunities) faces major economic, social and environmental challenges (Verma, 2024).

The logistics industry's current main task is to develop green logistics and adhere to the main energy-saving principles, emission reduction, green environmental protection, and efficiency improvement. Logistics companies should be oriented towards the protection of resources and care for the environment (Klimecka-Tatar, Ingaldi, 2021; Huang, Wang, 2022).

To achieve these goals, logistics companies should invest in fixed assets while managing their financial condition, including long-term solvency. In assessing this area, the golden balance sheet rule is useful. This rule presents recommendations for managing balance and stability in the financing of the enterprise (Nosková et al., 2022). These issues are important because there is a relationship between companies' sustainable behaviour and their financial performance (Martinez-Ferrero, Frias-Aceituno, 2013).

The article's main aim is to assess the impact of long-term solvency on the sustainable development of logistics enterprises (SD, section H of PKD 2007) in Poland from 2008 to 2022. We have chosen a section important for shaping GDP, stable development of society and other economic sectors.

The paper's novelty is treating long-term solvency (LTS) as one of the determinants of sustainable development. The golden balance sheet rule, which indicates that fixed assets should be financed entirely with fixed capital, limits the probability of a company losing financial liquidity and reduces its financial risk.

The research data was taken from the Central Statistical Office Database. They are annual. The central research hypothesis is as follows: Long-term solvency positively impacts the sustainable development of logistics enterprises in Poland from 2008 to 2022. To verify the research hypothesis, the Ordinary Least Square Method (OLS), the Vector Regression Analysis (VAR) and the Seemingly Unrelated Regression (SUR) were used.

2. Theoretical background

The rapid development of industry, urbanization and globalization have led to several changes in socio-economic life and have hurt the condition of the natural environment (Kichigin

et al., 2023). Significant environmental degradation and climate change have become challenging and require taking steps and initiatives to protect the natural environment (Roseland, 2000; Peng et al., 2020).

In economic theory and practice, various concepts have arisen related to the functioning and development of enterprises and their impact on the external environment. The most popular ideas are sustainable development (Teng et al., 2021; Misztal et al., 2024), corporate social responsibility (Aguinis et al., 2024), ecological and social responsibility (Chatterji, 2024), or eco-development (Asumah et al., 2024).

Sustainable enterprise development means the actions undertaken by enterprises in the economic, social and environmental spheres (Zuzek, Mickiewicz, 2014; Comporek et al., 2022). In the most straightforward sense, it means development that enables the development of the present generation without wasting opportunities and conditions for future generations (Matinaro et al., 2019).

Another approach shows that sustainable development of enterprises is a development that provides good conditions for current and does not exclude the interests of future stakeholders of the enterprise (Lorenc, Kustra, 2021).

Business practice is about making profits, sharing them, taking care of the development of local communities, and implementing environmentally friendly technologies. The goal is to create sustainable business strategies and a holistic approach to business in a changing and complex environment (Kaletnik, Lutkovska, 2020) (Figure 1).

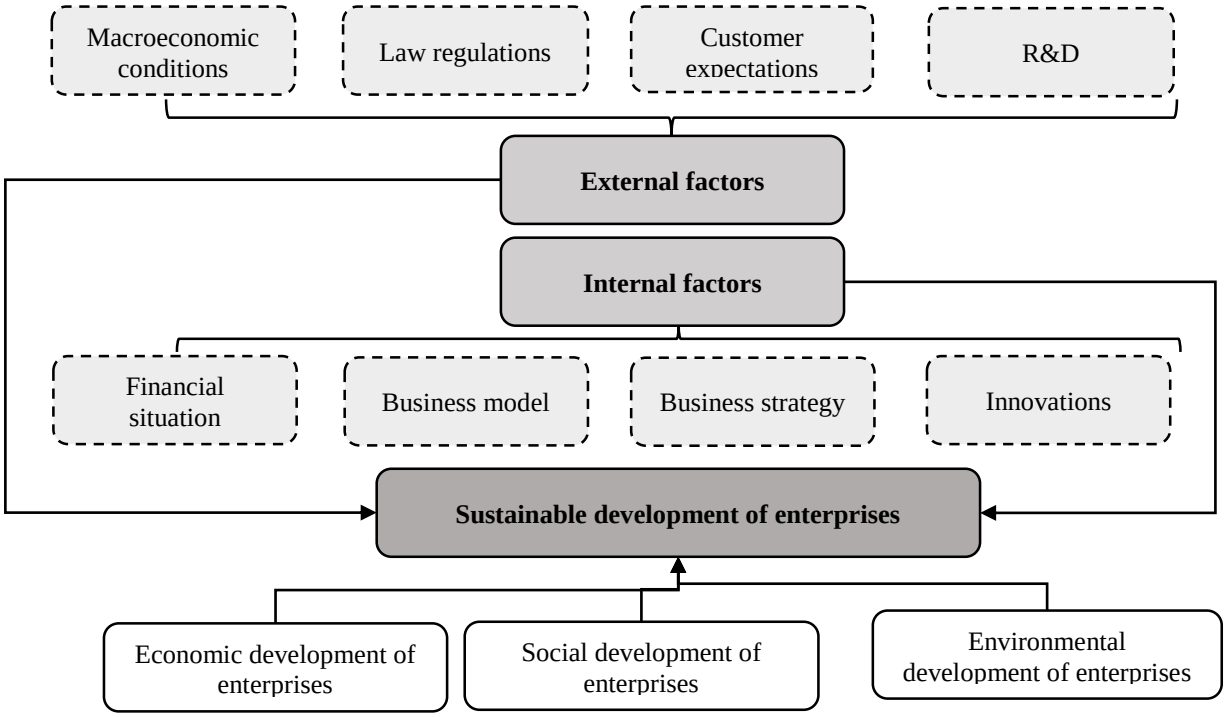

Figure 1. Determinants of enterprises sustainable development.

Source: own elaboration.

The effectiveness of implementing the goals and tasks of sustainable development requires the involvement of various institutions and organizations, including enterprises, which have significantly and negatively contributed to negative climate changes (Misztal, 2018).

External and internal factors determine the sustainable development of enterprises (Stoenoiu, Jäntschi, 2024). The first group includes issues related to economic development, scientific research development, economies' innovativeness, and regulations in employee rights and environmental protection. The second group includes issues related to the adopted business model and strategy, assets, financial and property situation, management style, and knowledge (Middermann et al., 2020; Diallo et al., 2024).

One of the factors important for sustainable development is a good financial situation. An important issue is the high level of permanent capital (Zhou et al., 2022). The financial golden rule index is the constant capital and fixed assets quotient. Fixed capital is a stable, long-term source of financing the company's operations. The value of constant capital includes the enterprise's capital and foreign capital at its long-term disposal. The constant capital use ratio is often called the ratio checking the fulfilment of the golden financial rule, a milder version of the golden balance sheet rule. The golden financial rule states that the company's fixed assets should be financed with stable sources of financing in the form of permanent capital, which is the sum of the company's equity and long-term external capital (Soda, Al-Shyyab, 2024; van den Hurk, 2024).

The golden financial rule is important because it allows for appropriate liquidity risk management and increases financial stability and cost efficiency.

3. Research methodology

The research's primary aim is to assess the impact of long-term solvency on the logistics sector's sustainable development in Poland from 2008 to 2022. The data for the analysis come from the resources of the Central Statistical Office. They are annual. The research sample includes logistics companies registered in Poland (Section H: Transportation and Storage).

The central research hypothesis is as follows: Long-term solvency positively impacts the sustainable development of logistics enterprises in Poland from 2008 to 2022.

In addition, we asked the following research questions:

- What is the dynamics of sustainable development of the logistics sector in Poland?
- What is the long-term solvency of the logistics sector in Poland?
- Does long-term solvency have a statistically significant impact on the pillars of sustainable development?

W conducted our research in stages. First, we form the indicator of sustainable development of logistics sector (SD). W use the formula:

$$SD_i = \frac{1}{n}\sum_{j=1}^{n} E_i + \frac{1}{n}\sum_{j=1}^{n} S_i + \frac{1}{n}\sum_{j=1}^{n} Env_i \; ; \; (i = 1, 2, \dots, n) \quad (1)$$

where:

SDi stands for the synthetic indicator in the i-year;

n is the number of metrics;

E_u – economic development in the *i*-year;

S_i – social development in the *i*-year;

Env_i – environmental development in the *i*-year.

Then, we transform the explanatory variables to unify their measuring scales using the following formulas:

- for the stimulants:

$$z_{ij} = \frac{x_{ij} - \min_i\{x_{ij}\}}{\max_i\{x_{ij}\} - \min_i\{x_{ij}\}}, z_{ij} \in [0; 1]; \quad (2)$$

- for the destimulants:

$$z_{ij} = \frac{\max_i\{x_{ij}\} - x_{ij}}{\max_i\{x_{ij}\} - \min_i\{x_{ij}\}}, z_{ij} \in [0; 1]. \quad (3)$$

where:

z_{ij} stands for the normalized value of the *j*-th variable in the *i*-th year;

x_{ij} is the value of the *j*-th variable in the *i*-th year;

$\min_i\{x_{ij}\}$ is the lowest value of the *j*-th variable in the *i*-th year;

$\max_i\{x_{ij}\}$ is the highest value of the *j*-th variable in the *i*-th year.

Evaluating the relationship between the SD and LTS required using certain simplifying assumptions and developing proprietary indicators. We normalised the SD and its pillars (E, S, Env) based on diagnostic variables divided into stimulants and destimulants (Table 1).

Table 1.
Diagnostic variables used in the SD and its pillars (E, S, Env)

Pillars of SD	Diagnostic variable	Description of the variable	Stimulants	Destimulants
Economic development (E)	x_1	Total number of companies in a country	+	
	x_2	Turnover or gross premiums [million euro]	+	
	x_3	Production value [million euro]	+	
	x_4	Value added at factor cost [million euro]	+	
	x_5	Gross operating surplus [million euro]	+	
	x_6	Total purchases of goods and services [million euro]	+	
	x_7	Gross investment in tangible goods [million euro]	+	
	x_8	Investment rate (investment/value added at factors cost) [%]	+	
	x_9	Share of personnel costs in production [%]		+
	x_{10}	Average personnel costs [thousand euro]		+

Cont. table 1.

Social development (S)	x_{11}	Wages and Salaries [million euro]	+	
	x_{12}	Social security costs [million euro]	+	
	x_{13}	Total number of employees in a country	+	
	x_{14}	Turnover per person employed [thousand euro]	+	
	x_{15}	Apparent labour productivity [thousand euro]	+	
	x_{16}	Gross value added per employee [thousand euro]	+	
	x_{17}	Growth rate of employment [%]	+	
	x_{18}	Number of persons employed per enterprise	+	
	x_{19}	Investment per person employed [thousands euro]	+	
	x_{20}	Personnel costs [million euro]		+
Environmental development (Env)	x_{21}	Carbon dioxide emission [tons]		+
	x_{22}	Methane emission [tons]		+
	x_{23}	Nitrous oxide emission [tons]		+
	x_{24}	Sulphur oxides emission [tons]		+
	x_{25}	Ammonia emission [tons]		+
	x_{26}	Carbon monoxide emission [tons]		+
	X_{27}	Nitrogen oxides emission [tons]		+
	x_{28}	Generation of total waste [tons]		+

Source: own study on the basis of Eurostat [https://ec.europa.eu/Eurostat], 16.08.2024.

In the next step, we use the OLS method to assess the impact of long-term solvency (LTS) on the SD (4):

$$SD_i = \beta_0 + \beta_1 LTS_i + \varepsilon_i;\ LTS = fixed\ capital\ /\ fixed\ assets \tag{4}$$

where:

β_0 is the intercept;

β_1 is the slope;

ε_i denotes the *i*-th residual;

I is an observation index.

The estimated models are given by the equations:

$$SD = \hat{\beta}_0 + \hat{\beta}_1 LTS_i + e_i = \widehat{SD}_i + e_i \tag{5}$$

so the residual for each observation is as follows:

$$e_i = SD_i - \widehat{SD}_i = SD_i - (\hat{\beta}_0 + \hat{\beta}_1 LTS_i) \tag{6}$$

The OLS procedure minimizes the sum of squared residuals:

$$s(\hat{\beta}_0, \hat{\beta}_1) = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (SD_i - \widehat{SD}_i)^2 = \sum_{i=1}^{n} (SD_i - \hat{\beta}_0 - \hat{\beta}_1 LTS_i)^2 \rightarrow min \tag{7}$$

To assess the impact of LTS on the E, S and Env pillars we built three structural equations based on the following formulas:

$$\begin{aligned} \mathrm{E_i} &= \propto_0 + \propto_1 LTS_\mathrm{i} + \propto_3 \mathrm{S_i} + \propto_4 \mathrm{Env_i} + \varepsilon_\mathrm{i} \\ \mathrm{S_i} &= \propto_0 + \propto_1 LTS_\mathrm{i} + \propto_3 \mathrm{E_i} + \propto_4 \mathrm{Env_i} + \varepsilon_\mathrm{i} \\ \mathrm{Env_i} &= \propto_0 + \propto_1 LTS_\mathrm{i} + \propto_3 \mathrm{E_i} + \propto_4 \mathrm{S_i} + \varepsilon_\mathrm{i} \end{aligned} \tag{8}$$

We use feasible generalized least squares (FGLS) to estimate the SUR model. The residuals from our regression are used to estimate the elements of matrix:

$$\hat{\sigma}_{ij} = \frac{1}{R} \hat{\varepsilon}_i^T \hat{\varepsilon}_j \tag{9}$$

Then, we run generalized least squares regression for using the variance matrix:

$$\Omega \equiv E[(\varepsilon\varepsilon^T|X)] = \sum \Omega \otimes I_R$$
$$\hat{\beta} = (X^T(\hat{\sum}^{-1} \otimes I_R)X)^{-1} X^T(\hat{\sum}^{-1} \otimes I_R)y \quad (10)$$

The formula for the SUR estimator is as follows:

$$\sqrt{R}(\hat{\beta} - \beta) \xrightarrow{d} \mathrm{N}(0, (\frac{1}{R}X^T(\sum^{-1} \otimes I_R)X)^{-1}) \quad (11)$$

To verify the autoregression of the SD we use the VAR model:

$$SD_t = c + A_1 SD_{i-1} + \varepsilon_t \quad (12)$$

where:

SD_{t-I} indicate that variable's value *i* time periods earlier and are called the "i-*th* lag" of y_t;

c is a *k*-vector of constants serving as the intercept of the model;

A_i is a time-invariant ($k \times k$)-matrix and e_t is a *k*-vector of error terms.

4. Research results

Table 2 presents the sustainable development indicators and their pillars. The economic indicator is increasing from 2008 to 2022, and the social development indicator of the logistics sector has similarly high positive dynamics. The increase in the environmental development index is positive, although less dynamic. The dynamics of sustainable development are positive; the indicator's highest level was in 2020, the first year of the pandemic; this is largely due to the temporary limitation of activities and, therefore, the lower emission intensity of the sector.

Table 2.
Sustainable development of logistics sector and its pillars in Poland from 2008 to 2022

Indicator	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
E	0,25	0,01	0,13	0,3	0,27	0,31	0,44	0,52	0,41	0,54	0,87	0,92	0,93	0,95	0,99
S	0,38	0,13	0,29	0,42	0,41	0,42	0,54	0,55	0,52	0,6	0,8	0,81	0,83	0,86	0,91
Env	0,41	0,61	0,44	0,51	0,58	0,65	0,67	0,57	0,39	0,27	0,18	0,71	0,96	0,6	0,61
SD	**0,35**	**0,25**	**0,29**	**0,41**	**0,42**	**0,46**	**0,55**	**0,55**	**0,44**	**0,47**	**0,62**	**0,81**	**0,91**	**0,8**	**0,83**

Source: own study on the basis of Eurostat [https://ec.europa.eu/Eurostat], 16.08.2024.

Figure 2 shows the dynamics of sustainability indicators and their pillars. The dynamics of economic development are the highest, while the dynamics of environmental development are the lowest. The dynamics of sustainable development are positive.

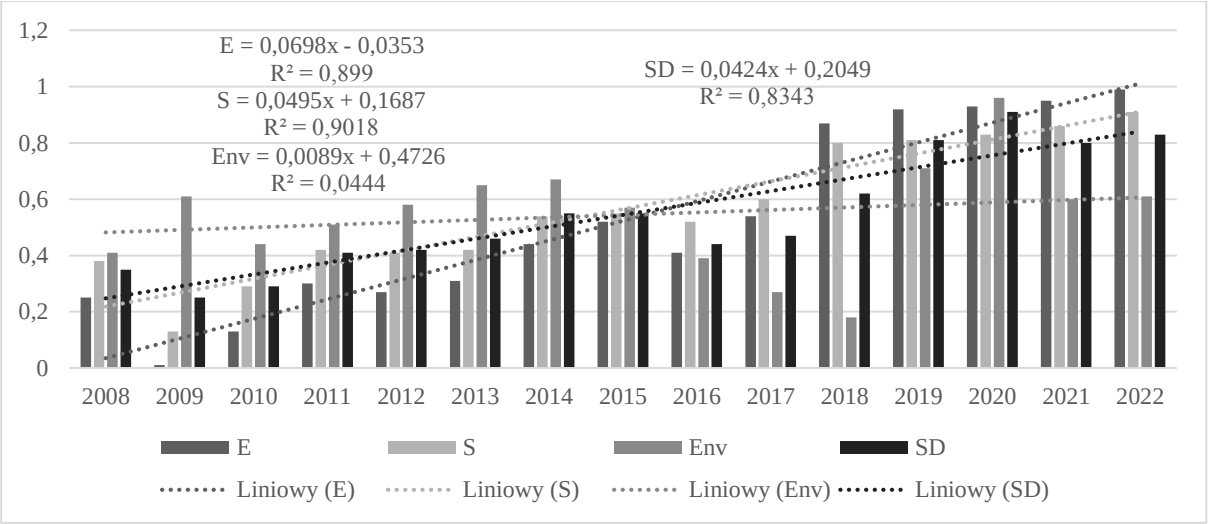

Figure 2. Sustainable development and its pillars from 2008 to 2022.

Source: own study on the basis of Eurostat [https://ec.europa.eu/Eurostat], 16.08.2024.

Figure 3 presents the long-term solvency (LTS) indicator of the logistics sector in Poland from 2008 to 2022. The dynamics of the indicator is positive, the value of the indicator exceeds 1 in the entire period.

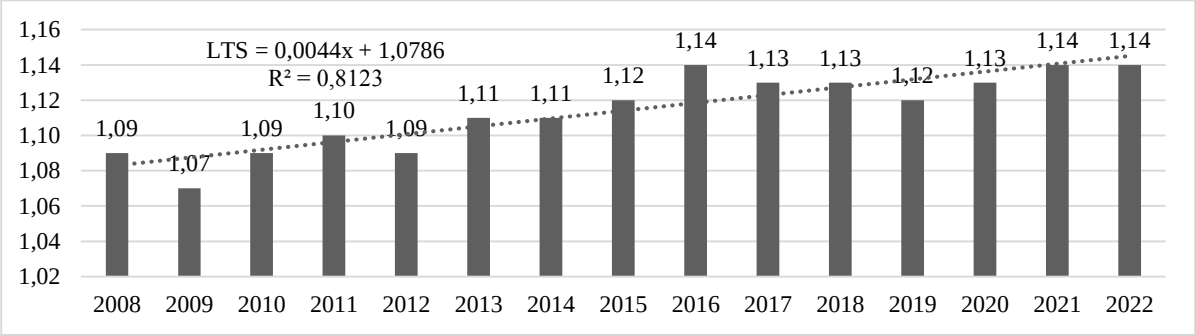

Figure 3. Long-term solvency of the logistics sector in Poland from 2008 to 2022.

Source: own study on the basis of Eurostat [https://ec.europa.eu/Eurostat], 16.08.2024.

The results of the OLS estimation are presented in Table 3. The impact of LTS is positive on the sustainable development of the logistics sector in Poland in the years 2008 to 2022. The results of statistical tests indicate that the estimation method can be used. Statistical significance was determined at $p < 0.05$.

Table 3.
The OLS, using observations 2008-2022 (T = 15); dependent variable: SD

	Coefficient	**Std. Error**	**t-ratio**	**p-value**	
const	−7.32651	1.93749	−3.781	0.0023	***
LTS	7.06509	1.73891	4.063	0.0013	***

Mean dependent var	0.544000	S.D. dependent var	0.207564
Sum squared resid	0.265731	S.E. of regression	0.142972
R-squared	0.559435	Adjusted R-squared	0.525545
F(1, 13)	16.50754	P-value(F)	0.001343
Log-likelihood	8.965819	Akaike criterion	−13.93164

Schwarz criterion	−12.51554		Hannan-Quinn	−13.94672
rho	0.544571		Durbin-Watson	0.912123

Non-linearity test (squares): LM = 0.112541 with p-value = P(Chi-square(1) > 0.112541) = 0.73727
White's test for heteroskedasticity: Test statistic: LM = 4.06437 with p-value = P(Chi-square(2) > 4.06437) = 0.131049
Test for normality of residual: Test statistic: Chi-square(2) = 2.57339 with p-value = 0.276182

Source: own study on the basis of Eurostat [https://ec.europa.eu/Eurostat], 16.08.2024.

The results of the autoregression are presented in Table 4. The impact of sustainable development from the previous period on the indicator level in the current period was recorded. Sustainable development is self-reinforcing, so decisions made in earlier periods bring results later.

Table 4.
The VAR system, lag order 1; OLS estimates, observations 2009-2022 (T = 14)

Log-likelihood = 13.946194
Determinant of covariance matrix = 0.0079850003
AIC = -1.7066
BIC = -1.6153
HQC = -1.7151
Portmanteau test: LB(3) = 5.13242, df = 2 [0.0768]

	Coefficient	**Std. Error**	**t-ratio**	**p-value**	
const	0.0681202	0.0749606	0.9087	0.3814	
SD_1	0.935377	0.134427	6.958	<0.0001	***

Mean dependent var	0.557857		S.D. dependent var	0.208075
Sum squared resid	0.111790		S.E. of regression	0.096519
R-squared	0.801381		Adjusted R-squared	0.784829
F(1, 12)	48.41711		P-value(F)	0.000015
rho	0.197569		Durbin-Watson	1.414483

F-tests of zero restrictions:
All lags of SD F(1, 12) = 48.417 [0.0000]
All vars, lag 1 F(1, 12) = 48.417 [0.0000]

Source: own study on the basis of Eurostat [https://ec.europa.eu/Eurostat], 16.08.2024.

Table 5 presents the SUR estimation results. The analysis results indicate that long-term solvency statistically impacts economic, social and environmental development. It should be noted that this impact varied in strength and direction of impact.

Table 5.
The SUR, using observations 2008-2022 (T = 15)

Dependent variable: E
coefficient std. error t-ratio p-value
const 1.50237 0.708055 2.122 0.0574 *
Long −1.70018 0.652000 −2.608 0.0244 **
S 1.53890 0.0572028 26.90 2.18e-011 ***
Env 0.0833371 0.0470972 1.769 0.1045
R-squared 0.988282 Adjusted R-squared 0.985086

Cont. table 5.
Dependent variable: S
coefficient std. error t-ratio p-value
const −1.01004 0.434169 −2.326 0.0401 **
Long 1.13331 0.393921 2.877 0.0151 **
E 0.647478 0.0241487 26.81 2.26e-011 ***
Env −0.0481905 0.0310751 −1.551 0.1492
R-squared 0.990296 Adjusted R-squared 0.987650
Dependent variable: Env
coefficient std. error t-ratio p-value
const 1.13811 0.312875 3.638 0.0034 ***
E 2.47824 1.07343 2.309 0.0396 **
S −3.34604 1.51924 −2.202 0.0479 **
R-squared 0.135299 Adjusted R-squared -0.008817

Source: own study on the basis of Eurostat [https://ec.europa.eu/Eurostat], 16.08.2024.

5. Discussion

The research results show that the dynamics of sustainable development of the logistics sector in Poland from 2008 to 2022 is positive, although its level varies in individual years. It should be assumed, like other researchers (Comporek et al., 2022), that the sector makes important investments, introduces ecological innovations, although on a limited scale, and supports the development of employees (Middermann, 2020; Aguinis et al., 2024). It should be noted that the general economic situation in Poland in the period under review was good; there is a particular shortage of drivers in the labor market regarding to logistics, and the financial and non-financial expectations of employees are increasing.

Our research confirms previous results in which researchers emphasize that financial factors are important for the sustainable development of enterprises (Matinaro et al., 2019; Misztal et al., 2024).

The OLS estimation results indicate that long-term solvency positively impacts the sustainable development of logistics enterprises in Poland from 2008 to 2022. Therefore, the main research hypothesis is true; therefore, maintaining the appropriate financial and property situation is important from the point of view of the credit position of enterprises.

The answer to the first research question is yes because the trend line of the sustainability index has a positive trend. It is a positive phenomenon, although it should be emphasized that a positive economic and social indicator determines the level of the synthetic indicator.

Long-term solvency fluctuates in the analyzed period (second research question), but it should be noted that the indicator has a positive trend, which should be assessed well from the point of view of corporate financial management.

Long-term solvency influences to varying degrees, both in terms of strength and direction of impact on the economic, social and environmental pillars. Moreover, company managers still focus on the economic and social development of the sector.

Theoretical implications are related to introducing a model written in an equation and a multi-equation model, allowing for assessing the impact of long-term solvency on the sustainable development of the logistics sector.

The empirical implications are that managers should consider the issues of managing the enterprise's financial and asset structure when making social and ecological investment decisions.

The research has limitations related to the availability of data, their selection, estimation methods, and the choice of the research period. Our study's boundary is assessing the impact of only long-term solvency on the sustainable development of the logistics sector; this is also an added value of the article because it needs an assessment of one of the most important factors. The choice of the exogenous variable is not accidental because long-term solvency is important for enterprises' stable operation and development.

6. Conclusion

Sustainable development of logistics from 2008 to 2022 has a positive trend, although the indicator values in individual years vary. The highest levels concern economic and social development, environmental development is at a lower level.

The VAR estimation results show that the level of the sustainability index from the previous period influences its current value. Therefore, decisions made in previous periods are important for the effects obtained in the future.

In turn, the OLS and SUR estimates show that long-term solvency positively impacts the sustainable development of the logistics sector and, in a diverse way, positively or negatively, on its economic, social and environmental pillars.

We will devote further research to analyzing the impact of financial security on the sustainable development of the logistics sector in selected European Union countries.

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